

ANNALS of SURGERY

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Edited by

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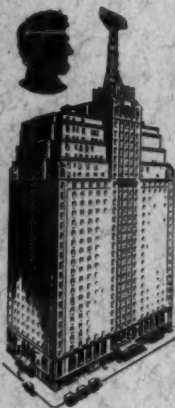
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ANNALS *of* SURGERY

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No. 1

SURGERY OF DIABETIC GANGRENE*

By ELDRIDGE L. ELIASON, M.D.

OF PHILADELPHIA, PA.

DIABETIC patients with gangrene are bad risks and need exceptional care and attention because of their advanced years, susceptibility to infection, delay in healing, and liability to acidosis. The present series of cases is no exception to that rule. In fact, this, perhaps, more than any other reported series, represents the worse risks possible, in that all of them were patients in a large city hospital, namely, the Philadelphia General Hospital, were of typical ward type, and most of them long unrecognized or untreated cases of diabetes before admission. The surgery was performed chiefly by four of the General Surgical Services.

An attempt is here made to give a statistical review of those cases of gangrene occurring in the diabetic patients in the Metabolic Wards of the above hospital, describing the treatment before, during and after operation. In 1926, the writer, together with Dr. V. W. M. Wright, reported fifty cases of amputation for diabetic gangrene, and at a later date, 1930, added 103 cases to this number. In the present article, further data are given on sixty-seven more cases of amputations. Consideration is given to the infections incident to the vascular disease, the precautions to be taken before and after operation, the type of anæsthesia employed, the specific surgical indications, the mortality, morbidity, and economic results as far as the patients' finally becoming useful citizens.

Incidence of Gangrene.—In the last three years, of 1,305 diabetics admitted to the Philadelphia General Hospital, 175, or 13 per cent., developed gangrene requiring surgery, a high incidence when compared with Allans' figures for the year 1931 at The Mayo Clinic where of 684 diabetic patients only seventeen were operated upon for gangrene. Records are available at the University of Pennsylvania Hospital on 355 diabetics before the year 1923 and before insulin therapy. The per cent. of gangrene in this number was 2.5. In 845 diabetics treated in the same hospital since 1923, the occurrence of gangrene was present in 6.2 per cent. The sex distribution in the above 175 cases was about the same. The ratio of occurrence in the white and Negro patients in this series was as 4 to 1. Fifty per cent. of the patients did not know they had diabetes until admitted to the hospital with gangrene; 96 per cent. of the gangrene occurred in the lower extremities. The average age of these patients was sixty-five years. General statistics throughout the country reveal that 20 to 25 per cent. of diabetic patients die of gangrene.

* Annual Oration before the Philadelphia Academy of Surgery, January 2, 1933.

ELDRIDGE L. ELIASON

Our own follow-up figures show that 58 per cent. of diabetic patients suffering with gangrene are dead within one year. These figures show the reason for the interest in diabetic gangrene, the seriousness of the condition, and why meticulous attention must be given all patients suffering with the condition and all diabetic patients who are apt to develop it. The age of the diabetic patient with gangrene determines to a great extent the prognosis. Gangrene seldom occurs in a youthful diabetic except as an embolic affair. Gangrene is a condition resulting from an inadequate blood supply which is usually the result of endarteritis obliterans.

Every untreated diabetic patient develops arteriosclerosis by the fourth decade. Arterial disease has been shown in diabetics under twenty years of age. Elsewhere it has been shown¹ that the diabetic form of gangrene occurs ten years earlier in life than does the senile form. Autopsies and operations on patients suffering with diabetic gangrene of the lower extremities show that the sclerosis is general, affecting particularly the coronary arteries, which condition is responsible for many of the deaths. Table I shows the comparative age of occurrence of gangrene in the present series and that of six

TABLE I
Occurrence

Status	Year	30-40 %	40-50 %	50-60 %	60-70 %	70-80 %	80-90 %
Occurrence.....	1926	1.8	5.5	52.7	29.1	11	...
Occurrence.....	1929-1932	1.2	8.6	22.0	46.0	18.4	1.8

Note the shift to the right after sixty years of age.

years ago. The vascular condition is the underlying and determining factor in the cause of diabetic gangrene. Joslin, in 1923, found the average age for the development of diabetic gangrene to be sixty-one years. In 1926, we found it to be 59.2 years in ward cases. McKittrick and Root, in 1928, found the average age to be 64.1 years. In 1931, we find that gangrene has been delayed to the average age of 69.9 years. This represented a postponement of gangrene for more than ten years, a distinct advance in the welfare of the diabetic patient. Unfortunately, the figures dropped back to 61.6 in 1932, making an average of about 7 years. While improved results in the treatment of diabetics have of late been justly attributed to insulin therapy, modern surgical principles especially applicable to the diabetic have improved the mortality and morbidity results, as far as diabetic fatalities are concerned. There has been little change in the surgical results. (Table II.)

TABLE II
Age and Incidence of Gangrene

Author	Year	Average Age
Joslin.....	1923	61.0 years
Eliason and Wright (50 cases).....	1926	59.2 years
McKittrick and Root.....	1928	64.9 years
Eliason and Wright (103 cases).....	1931 (1st series)	69.9 years
Eliason (67 cases).....	1932 (2nd series)	61.6 years

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The age of the patient should ever be borne in mind in the surgical treatment of these patients. The fact that insulin and other factors have advanced the age of occurrence of gangrene seven years indicates immediately that we are dealing with a worse risk than formerly and therefore must be more radical than ever in its treatment. Temporizing methods are dangerous where tissue resistance, the vascular system, the heart, lungs and the metabolism are in such a state that they easily develop myocardial failure, hypostatic congestion, pneumonia, uræmia and septicæmia, when procrastinating and insufficient surgical measures are adopted. The older the patient and the worse the risk, the more radical must be the surgery if life is to be saved and healing of the wound is to be obtained. Operations should be performed early, quickly, and at a sufficient high level to obtain good blood supply.

Susceptibility to Infection.—Diabetic patients are particularly prone to develop infections, and, what is more to the point, they never bear it well. This is especially true when the infection is closed and undrained. Infection in a diabetic spells hyperglycæmia, acidosis, a poor response to insulin and metabolic therapy, and coma which often results in death. Procrastination in seeking surgical advice or delay in operating in such cases increases the mortality. A diabetic patient with moist gangrene, cellulitis, gas-bacillus or other infectious process, immediately becomes a serious case. Previously easily manageable, he now becomes much more difficult to diet regulation and insulin therapy. In such cases operation is necessary. Once early drainage, excision or amputation of the offending infectious process is accomplished, the temperature, pulse and respiration, acidosis and insulin therapy drop to normal standards.

Because the diabetic is more prone to infection, bears it poorly and responds immediately to the elimination of it, his advisor should be on the watch for early infection and immediately seek the advice of a surgeon acquainted with and interested in diabetic surgery. Such team work results in the best possible management of surgical diabetes. Under these circumstances it can readily be seen that prevention of infection before surgery is necessary and will lower the mortality and morbidity. With this in view, the Metabolic Division has only especially trained nurses in the wards whose business it is to see that their patients have the best of hygienic care, especially of back and feet; when gangrene threatens sterile precautions are applied to that particular part. In addition, a chiropodist is on duty to care for corns, calluses, etc.

Conditions Demanding Operation.—From the standpoint of gangrene alone, the conditions demanding operation are, in priority of importance; gas gangrene, gangrene with cellulitis, moist or open gangrene, and dry gangrene. An analysis of our recent cases of gangrene shows that 87 per cent. entered the hospital with moist gangrene or developed it while there. This justifies consideration. Moist gangrene is potentially infected and is soon

followed by local pus and rapidly spreading cellulitis and lymphangitis. Dry gangrene should be kept so.

Gangrene which is demarcated and without visible or clinical signs of infection may be treated conservatively (electric-light cradle or dry dressings). Moist gangrene, however, deserves careful attention as far as anti-sepsis, and supportive measures (dry heat, dry dressings, or electric cradle) prior to amputation. Since moist gangrene is often followed by cellulitis, it behooves the observer to be on the watch for lymphangitis and cellulitis and to immediately seek early and adequate drainage or high amputation above the line of infection. Procrastination and conservatism are the pitfalls of internists and operators.

Occasionally, gas-bacillus infection enters the picture. Here no delay can be tolerated by the patient. Immunizing treatment and immediate excision or incision must be resorted to within a period of minutes or hours. Speed in the treatment of this dread infection cannot be overemphasized. Disproportionate pulse hurry with either a slight recognizable foul odor or slight subcutaneous crepitations, and with or without the usual late signs of typical discoloration and frothy discharge indicate immediate opening of the wound, or incision, excision and complete drainage of the suspected area. The condition has a high mortality despite the best efforts in treatment.

Preparation of Patient for Operation.—In comparison with past surgical treatment of the surgical diabetic patient, the patient now arrives in the operating room as nearly balanced metabolically as it is possible to make him. Carbohydrate, fluid and insulin requirements have been adjusted as far as possible to lend the patient the reserve, physiologically, that a normal patient has to possess for an operation. Operation is deferred until the metabolic needs are taken care of or improved. A few hours are usually sufficient in which to prepare the patient.

As this part of the care of the patient is entirely in the hands of the metabolist, Dr. Edw. S. Dillon, chief of the department, has kindly outlined the following:

Pre- and Post-operative Care of Diabetic Surgery.—The principle upon which all pre- and post-operative care in diabetes is founded is to see that the patient receives three carbohydrate meals equal to the prescribed amount of carbohydrate in a twenty-four-hour diet. If this is done, and enough insulin administered to keep the blood sugar normal, the patient will not develop ketosis.

Of necessity, during so crucial a time in the diabetic's life, the diet must be light and easily taken. In many cases a concentrated liquid diet will suffice, but in more extreme cases the diet must be administered by tube, hypodermoclysis, or even intravenously.

The Choice of Anæsthesia.—It is a well-known fact that certain anæsthetics tend to produce acidosis. This is a factor in the order of choice of

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anæsthetics to be used and the anæsthetics in order of their desirability are as follows:

(1) Local Anæsthesia: Produces no changes in metabolism and is to be preferred in all cases where minor operations are performed and other cases that would not stand a general anæsthetic.

(2) Spinal Anæsthesia: Also causes no disturbance in metabolism and is the anæsthetic of choice born of necessity in operations on the lower extremities, perineum and lower abdomen, providing there is no contra-indication due to the patient's general condition.

(3) Nitrous Oxide Oxygen: Does not tend to produce severe metabolic disturbance unless unduly prolonged. Not a good anæsthetic, however, when relaxation is desired.

(4) Nitrous Oxide supplemented with Ether: Produces better relaxation, more apt to cause acidosis, due to the ether.

(5) Ether: If prolonged it is certain to be followed by acidosis, as indicated by fall in the carbon-dioxide combining power. It can be used, however, if this fact is borne in mind and the necessary post-operative measures taken to combat acidosis.

(6) Chloroform: Produces an extreme acidosis and is mentioned only to be condemned. It should never be used on a diabetic.

As a routine on all surgical diabetics a blood-sugar and carbon-dioxide combining power should be performed on all patients prior to operation. If the CO_2 shows any appreciable drop below normal operation should be deferred until the acidosis has been treated. This is an inviolate rule, even if the operation is designed to remove the cause acting to produce acidosis. A patient will survive the operation, but very often will not survive the acidosis following the operation. On the other hand, if the acidosis is treated first, he will survive them both. A routine blood sugar and CO_2 should be performed within five hours after operation, especially if anæsthetics in groups of 3, 4, and 5 are used.

Insulin.—Granted that the patient has been well standardized before operation, we continue his required dose, increasing it as required when the blood sugar tends to rise. For this reason it is necessary to have daily blood sugars or even sugars at twelve-hour intervals in the more severe diabetics.

Indication for Operation.—In general, it may be stated that the indications for operation are identical with the non-diabetic. The presence of diabetes is not a contra-indication for any operation, providing the pre- and post-operative care can be supervised by one familiar with metabolic treatment. In fact, there are some cases in which the presence of diabetes more strongly indicates prompt operation. Any collection of pus, as the result of infection in a diabetic, demands prompt incision and free drainage, and this is a motto in diabetic surgery. A diabetic's life may be lost in deferring a leg amputation twenty-four hours. The absorption of the products of an infection is attended with decreased carbohydrate tol-

erance and a resulting tendency toward acidosis. Experimentally, pus can be mixed with insulin and injected into a laboratory animal with no hypoglycæmic response, showing the neutralizing effect of pus upon the insulin in the diabetic's body.

In operations upon extremities, incision and drainage of abscesses, the patient receives an enema the night before. In amputations of the lower extremities, spinal anæsthesia is generally used, whereas in the other operations, local or short nitrous oxide oxygen anæsthesia is required. All cases of amputation receive a prophylactic dose of 25 cubic centimetres perfringens antitoxin before operation. The morning of operation the patient receives orange juice, enriched with glucose, with the usual dose of insulin. This is given in the morning at 6 A.M., in order to allow its passage through the stomach, and thus diminish the danger of vomiting when nitrous oxide and oxygen are used. The patient, of course, receives pre-operative morphine and atropine. If not nauseated and vomiting following operation, patient is allowed orange juice. Very often it is advisable to pass a gastroduodenal tube immediately upon the patient's return to the ward, and administer orange juice, glucose and fluids by this route. Of course, if the patient is nauseated and vomiting, the carbohydrate must be administered in saline, either hypodermically or intravenously. Nausea and vomiting should be treated by passing a tube and lavaging the stomach with warm 2 per cent. sodium bicarb.

Fluids.—Fluid intake before and after operation is even more important in diabetic patients than in others. In the latter, one can be content with a daily intake after operation of 2,400 cubic centimetres, but in the diabetic, 3,000 cubic centimetres, or more, are needed during the twenty-four hours preceding and following operation. This avoids dehydration. To accomplish this, a charted amount is administered by mouth, Jutte tube, under the skin or intravenously, and a daily intake and output chart kept as long as needed. Saline or tap water may be supplied by bowel also, but glucose by bowel has been discarded by the author as unreliable in supplying a desired caloric requirement. Blood-sugar determinations before, during and after the administration of glucose by bowel in a series of diabetic cases attest the conclusion that it cannot be relied upon to supply caloric needs.

Specific Treatment.—The local and general care of gangrene depends upon its type and extent as well as upon the general condition of the patient. Dry gangrene, moist gangrene, gangrene complicated by cellulitis or frank pus and gangrene with gas-bacillus infection require different treatment. Temporizing or conservative measures may be adopted with the first, but not with the latter. The author is generally in favor of high (mid-thigh) amputations, but does occasionally perform the Stokes-Gritti and other lower amputations by request or where special circumstances indicate that a low amputation is justifiable.

Dry Gangrene.—Dry gangrene is never considered a condition requiring immediate operation. Because of this, conservative treatment is given.

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This consists of an electric-light cradle over the foot of the bed to keep the area dry, maintain warmth, promote good circulation and avoid pressure over the affected part. Simple dry dressings may be used if desired or proved to be more practical. Conservative treatment in these cases permits sufficient time to standardize the patient's metabolic requirements and for the formation of a line of demarcation in these few cases where a low or leg amputation is to be considered.

Moist Gangrene.—Eighty-seven per cent. of the 170 cases were of the moist gangrene type. This figure is entirely too high with our present early detection of diabetes. Advice should be given all diabetic patients, and physicians as well, to avoid moist dressings and ointments at the first sign of an infection or early gangrene. Heat and moisture together are not borne well by diabetic tissues and often an infection or threatened gangrene is made worse by maceration through the popular treatment of hot salt-water dressings or the sealing in of infection by an unguent.

In comparison with the dry form of gangrene the moist type is usually attended by lymphangitis or some cellulitis. Because a diabetic cannot handle infection well it is customary to operate upon these cases as emergencies. Invariably they are operated upon at least within twenty-four hours. Simple dry dressings or the electric-light cradle is used temporarily to treat the condition locally and the extremity is elevated. The patient is fairly standardized by morning as a result of the metabolic treatment previously outlined. All cases of this type should be drained as the stump above the level of gangrene is traversed by lymphatic vessels and veins which have been carrying infection upward. A split tube in the depths of the wound before closing will usually insure adequate drainage. The drain is removed within twenty-four to forty-eight hours. If infection makes its appearance, the wound is opened freely.

Infected Gangrene.—Gangrene complicated by cellulitis or frank pus is a serious condition and should be treated as an emergency. This condition is often the result of neglected moist gangrene and is another indication for early operation in such cases. A diabetic patient with infected gangrene usually presents a high temperature, pulse, respiration, acidosis or impending acidosis, delirium and toxicity. They respond poorly to insulin and metabolis measures. These are the cases that respond so rapidly to incisions, judiciously timed and placed, or high amputation with drainage or the stump left open. It is unwise to wait, here, for standardization of the patient's metabolic condition. One can only delay a few hours to prepare the patient as well as possible for an immediate operation. We only delay if laboratory examinations show the presence of severe acidosis. Then alkalies are administered, glucose and insulin are given in extra amounts until the patient's CO_2 is within or near normal limits. First, a blood-sugar and CO_2 determination are made. This indicates the amount of glucose and insulin that should be given to temporarily tide the patient through the operation and prevent further acidosis. Glucose is given intravenously, insulin

hypodermically and a Jutte tube is passed and left in place for immediate post-operative introduction of lactose and fluids. As these patients are often delirious or semicomatose, fluid and carbohydrate intake are assured by administration of the same through the tube. When the cellulitis has extended high up the limb, a guillotine amputation left open is indicative.

Gas-bacillus Infection in Gangrene.—Within the last two years we have encountered fourteen cases of gas-bacillus infection in patients with diabetic gangrene. Owing to the susceptibility of diabetic patients to infection, the presence of gas gangrene is even more dreaded than in other patients. Ten of our cases were post-operative complications. Immediate wide excision and drainage or higher amputation must be performed. Where a stump has become infected, it is best to immediately cut all sutures, lay the wound wide open, débride all questionable tissue and irrigate frequently with peroxide or Dakin's solution. Even with the best of treatment the mortality in gas-bacillus infection in diabetics is extremely high. Perfringens antitoxin should be given intravenously and intramuscularly in twenty-five to fifty cubic centimetres doses and repeated as indicated depending upon the individual case. Repeated excision of chocolate-colored and frothy muscle or high amputations may be necessary. The treatment of gas-bacillus infections in diabetics has been extremely disappointing in our hands. The fact that 78 per cent. of our cases with gas infection have died indicates why we feel the way we do. Our present feeling is that, if properly immunized previously, a diabetic stands a fair chance toward recovery. If, on the other hand, he has not been immunized against it, his poor circulatory and physiological condition precludes the results often observed in non-diabetic patients in whom the mortality is not nearly so appalling. During one period when perfringens serum was available, thirty-three of forty-three cases obtained it before amputation; in this number four developed the infection, of which two died.

Operative Consideration.—In considering what operation to perform upon a patient with diabetic gangrene, less consideration should be given as to where and how much gangrene is present, than to how old is the patient, with regard to the vascular disease how old is the gangrene, and how much infection is present. The immediate condition and result should not necessarily take precedence over the future result. Rather should the latter be considered first and then the proper procedure be determined upon. A patient with dry gangrene, in the forty to fifty decade, can often suffer an amputation of a toe and have no further trouble for a number of years. Another, of the same age, with cellulitis and lymphangitis, or still another who is sixty years of age, but with dry gangrene of the foot or ankle will do better, in the long run, with the high amputation. Local and general conditions must be weighed in every case and each should be treated individually, but under broad general and basic principles. Experience shows that, as a general measure, high amputations are preferable. Various statistics and immediate results are often misleading. Careful consideration of post-operative and end-

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results frequently shows that preconceived and hoped-for results are not borne out. For example, in amputations performed below the knee the hospital mortality (thirty days) was 56 per cent.; in amputations of the mid-thigh area, the mortality was practically the same, 55.8 per cent. These figures constitute only immediate results and banish the fear that the thigh amputation gives a greater surgical mortality rate. End-results showed, moreover, that none of the high amputations required further surgery, but that in those with operations performed below the knee, multiple surgical intervention was necessary with an increase of 15 to 20 per cent. unfavorable results. It is of interest to note in Table V that in the series of twenty-five deaths, eleven of the cases were noted to have had extension of the gangrenous condition as a causative factor in their death. This, of course, is indicative of poor blood supply at the operative site. If above the knee, it indicated a hopeless situation; if below the knee, it probably meant too low an operative level. In a previous article we have shown that re-amputations or multiple surgical procedures are attended by an increased hospital mortality of 15 per cent. in comparison with primary high amputation. In our recent cases with improved care, the futility of conservative and procrastinating surgery is clearly shown. In selected cases conservative operation is justifiable. As a workable thesis we believe that the lower the amputation the higher the mortality and conversely, the higher the amputation the lower the mortality. In fifteen cases where procrastinating surgery had been performed, there was a mortality of 66.6 per cent. (in comparison with 55.8 per cent.) and 86.5 per cent. unfavorable results, resulting in thigh amputation finally.

Anæsthesia.—Selective spinal anæsthesia is used routinely in gangrene of the lower extremities. Eighty per cent. of the cases were operated upon under spinal anæsthesia, 17 per cent. under local and only 3 per cent. had gas or ether. Spinocaine and novocaine were the agents generally used. By selective spinal anæsthesia is meant the selecting of the level of operation and the placing of the level of anæsthesia to a point just above the operative site instead of the routine administration of trunk anæsthesia. With rare exceptions all thigh amputations had spinal anæsthesia.

When operations are performed with a low blood-pressure, many bleeding vessels are not visualized at the time and consequently are not ligated. This low pressure can be prevented by ephedrin given twenty to thirty minutes before the anæsthesia is administered. When the fallen blood-pressure returns to normal later on, hæmorrhage occurs, and the wound has to be opened or it will often become infected. Local anæsthesia has a tendency to traumatize and so further devitalizes the already weakened tissue; gas anæsthesia is not a safe anæsthetic in old patients with high blood-pressure and arteriosclerosis.

Operative Technic.—After pre-operative consideration, operations should be performed quickly, neatly and thoroughly. Teamwork is essential. A mid-thigh amputation can be performed in a very few minutes. Under low

spinal or a short gas anæsthesia, there is hardly any reason why almost any properly prepared diabetic patient cannot be relieved of a menacing gangrenous limb.

Without a tourniquet the limb should be removed by the transfixion method. Care should be used in not making long and thin antero-posterior flaps. It is best to make the flaps as short as the condition of closure will permit. The transfixion method is much quicker and less traumatizing than the dissecting and prosthetic method. The Gritti-Stokes operation is sometimes used. Rigid hæmostasis is required to prevent hæmatomas that lead to infection. Hot saline irrigations prior to closing both remove all blood-clots and stimulate muscle ends made cold by air exposure. No attempt is made to suture individual muscles to each other, thus avoiding constricting muscle sutures that result in necrosis. Muscle bundles are, however, approximated by fascial sutures and wound compression. Interrupted mattress sutures of iodine catgut insure contact and allow for wound tension. Drainage is inserted and the skin edges are approximated by interrupted silk sutures. The latter have the advantage that if a localized hæmatoma or infection occurs, the wound can be opened at that point by clipping a single suture without detriment to the rest of the wound. A large dressing of loose gauze is then applied to the stump and the operation is completed.

Drainage and Post-operative Dressings.—Infection, latent or present, is often not suspected. Especially is this true in diabetic patients. Since a drain causes no harm and is an excellent insurance if infection be present, it seems desirable. In some cases a drain has been placed in the depths of the wound reaching down to the bone end. This is withdrawn in twenty-four hours if no infection appears. Laterally, however, we have introduced a drain designed to meet physio-anatomical requirements with happy results. This consists of a drain inserted through a stab puncture, before the wound is closed, in such a manner that the tube drains postero-laterally at a point opposite the bone end. As the most comfortable stump position is slight flexion, this method of draining permits postural drainage, comfort and freedom from excretory soiling. Table III shows the incidence of wound infection and the reason why drainage is desirable. In badly infected cases, with cellulitis and lymphangitis, the guillotine operation is employed and no suture used.

TABLE III
Wound Complications

Closed Wounds	Cases	Per Cent.
Clean.....	49	44.1
Type A (Serum).....	13	11.7
Type B (Stitch abscess).....	2	1.8
Type C (Break down).....	47	42.3 +
Totals.....	111	99.9

NOTE.—Type C is the only serious complication jeopardizing wound, increasing hospital stay or endangering life.

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Type of Operation.—Seventy-six per cent. of the amputations were in the thigh, 10 per cent. were primarily leg amputations which required a higher operation later, only the lower operation being permitted by the patient or family at first. Minor operations comprised 14 per cent. of the cases which were either too ill or permission was not obtainable for a higher removal. Five of the 175 refused treatment.

Delayed Healing.—Clean wounds in diabetics do not heal as kindly as in non-diabetics. Because of the increased susceptibility and the decreased resistance of the diabetic patient, wound complications in the diabetic occupy a higher ratio than in others. This is a result of local tissue changes which may be divided under the head of altered vascular and metabolic function. Forty-two per cent. of the amputation wounds showed some form of infection resulting in a severe diffuse suppuration. This is a vastly higher incidence of wound infection than occurs in general surgery where it runs from 4 to 6 per cent. Since wound infection has such a high incidence, it behooves us to drain all cases to obtain a dry wound free of blood and serum. From time to time cases are cited that heal perfectly when closed "tight." All too often this does not occur. A small drain to the cut end of the bone does much good and no harm in its twenty-four-hour stay. Experience and statistics bear this out in the present series, but it is only fair to state that other writers close all such wounds with reported good results. These figures are very bad and could be charged possibly to poor technic, but the reader will recall that 87 per cent. of these cases were primarily infected, and hence probably had cellulitis or at least lymphangitis at the site of operation before the incision was made. Studies instituted since this was written have shown in some instances that cultures taken at the time and site of operation have revealed organisms present there similar to the organisms found in the lesion lower down.

Of the serious wound infections (pus) forty were cultured. Table IV shows the prevailing organisms. The high incidence of gas-bacillus infection is attributable to a certain brand of catgut on the market as was proved by laboratory cultures and controls of used and unused material. An occasional case of gas-bacillus infection may be encountered in amputation cases where the patient is incontinent, delirious, or where for other reasons the contents of the intestinal tract have soiled the amputated area before or after operation.

TABLE IV
Type of Wound Infections

Organisms	Cases	Died	Mortality %
B. Welchii.....	14	11	78
Hæm. Strep.....	13	8	60
Strep. Viridan.....	3	2	66
Staph. Aureus.....	5	1	20
B. Proteus.....	3	0	0
B. Diphtheriae.....	1	0	0
B. Coli.....	1	0	0

The hæmolytic streptococcus and the *streptococcus viridans* seem to be the organisms most generally dangerous to the diabetic patient. Leaving the incidental gas-bacillus infections out, these two organisms represent 47 per cent. of all infections and are concerned in 95 per cent. of the mortality in the infected cases.

Operative Complications and Results.—Previous to 1927, 37.5 per cent. of the diabetic gangrene patients died of diabetes. This was due partly to the prevailing treatment. Surgical diabetics were admitted directly to the surgical wards and received varying types of surgical and medical treatment. The surgical condition usually received early operative intervention, which was often performed under ether anæsthesia, and starvation before and after operation, which practice only tended to increase acidosis and mortality. The metabolic requirements of the patient were injudiciously handled by a surgeon or an occasional visiting medical consultant. In other words, the surgical condition was treated first and the metabolic condition secondarily, and often inadequately. Neither is sufficient without the other.

The present series of cases represents an entirely different method of treatment. This group was admitted to the metabolic ward, treated there for their diabetes and operated upon after surgical consultation. In the past the surgeon has erred as far as adequate metabolic treatment is concerned. Now that diabetics reach the medical man first, he must not err, as has the surgeon previously, to seek early consultative advice. Whereas teamwork always works for the best, here it is imperative. Procrastination or independence on the part of either the surgeon or metabolist works for only one end-result—increased mortality.

Operations under the older form of surgical treatment (routine starvation before and after operation, ether anæsthesia, low fluid and carbohydrate intake afterward) have been superseded by the elimination of starvation, dehydration and acidosis through proper preliminary standardization, caloric and fluid requirements, spinal or gas anæsthesia and proper metabolic treatment immediately after operation. The latter method makes for a lower incidence of acidosis and of complications, and for better operative results.

Results.—In comparison with results of five years ago, today's results are both disappointing and pleasing. Immediate operative results are no better, but end-results seem to be a little better. Improved metabolic treatment, better preparation of the patient for operation, and improved anæsthesia technic have worked for a much lower mortality due to diabetes *per se*. The reason for poor end-results is accredited to the patient's age. In 1926, the average age of individuals developing gangrene under the then existing form of treatment was 59.2 years. Now that improved metabolic treatment has advanced the age of occurrence of gangrene to 65.6 years, we have a more diseased patient to cope with. Not only is his diabetes in a more advanced stage, but his kidneys, heart, lungs and tissues are much weaker than a decade previously. Added to this (which is the most important) his arterial tree is far more sclerosed than before. As gangrene depends upon inade-

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quate circulation and its prognosis upon the arterial tree above, it is obvious that we are dealing with a worse risk than previously.

An analysis of the last five years shows that 42 per cent. of diabetic patients with gangrene died in the hospital and that 55 per cent. were dead within a year. The higher per cent. figures are those including ten cases of gas-bacillus infection. Surely this is not very cheering. Despite these gloomy figures, though, the diabetic patient with gangrene is better off today than five years ago as he lives about seven years longer before gangrene appears.*

Causes of Death.—As stated above, the commonest cause of death in these cases is myocarditis with coronary thrombosis. Many other contributing factors are usually concerned in each case, so that three and four—sometimes five—diseases will appear on their post-mortem sheets. Table V lists the conditions and the frequency of their occurrence in twenty-five deaths as entered on the death certificate.

TABLE V
Causes of Death (25 Consecutive Cases)

Disease	No. Cases
Diabetes.....	25
Myocarditis.....	17
Infection (including gas and streptococcus).....	8
Gangrene (extension of original process).....	11
Sclerosis (advanced).....	6
Toxæmia.....	4
Senile dementia.....	4
Pneumonia.....	4
Miscellaneous (decubitus, senility, etc.).....	8

It will be seen that in eleven of the twenty-five cases, extension of gangrene in the stump was noted. The anterior flap was the one chiefly involved, meaning that this flap had the poorer blood supply. This bears out the observation of the writer made at the time of operation, namely, that more ligatures are necessary in this flap. The literature confirms this in the finding of increase in the size of the arterial trunks in the sciatic tree. This increase is very marked in the supply of the sciatic nerve itself.

Follow-up and Economic Considerations.—In 1926, our operative mortality (twenty-four hours) was 3.6 per cent. and our hospital mortality (thirty days) 43.6 per cent. We had no follow-up at that time. With improved metabolic treatment, anæsthesia and operative technic, we naturally expected a vast improvement. Actual figures, however, show that in 1929-1932 the

* Figures obtained from the University of Pennsylvania records show that the average age at death of all diabetics before insulin in 1923 was thirty-seven years and since the advent of insulin, the average age at death has been fifty-one years, an addition of fourteen years to the diabetic's life. One can easily appreciate when comparing these figures, fourteen with the seven at the Philadelphia General Hospital, the difference in the character of the material at these two hospitals. In both hospitals the post-mortem reports show that circulatory disease has been by far the most pronounced cause of death.

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operative mortality is 3.5 per cent. and the hospital mortality (thirty days) is 41.8 per cent.; but the follow-up mortality for one year is 55 per cent., as against 61.1 per cent. years mortality two years ago. The one-year mortality figures include the operative as well as the hospital mortality. (Table VI.)

TABLE VI

Mortality Figures

Year	Operative (24 hours)	Hospital (30 days)	1 Year
?-1926 (50 cases).....	3.6%	43.6%	61.1%
1929-1932 (170 cases).....	3.5%	41.8%	55.0%

The very nature of our follow-up problem in this class of patients with frequent change of address, many of them foreigners, the wide area of the entire county of Philadelphia to be covered and oftentimes the difficulty of location and time consumed in long distance calls, hampers the collection of data. In the last eighteen-month period (January, 1931 to July, 1932) of sixty-seven cases operated upon, thirty-four cases left the hospital alive, and of these twenty-eight have been followed. (Table VII.)

TABLE VII

Mortality Figures (Continued)

No. Cases	Months after Operation	% Living
28.....	1- 6	100.0
20.....	6-12	71.0
8.....	12-18	28.5
3.....	18-24	10.4

It is seen from this limited number that only 10.4 per cent. are alive after eighteen months.

Joslin has remarked that a gangrenous diabetic toe costs some one (patient or taxpayers) \$500. Conservative treatment and multiple operations with increased mortality and funerals are apt to double this figure to \$1,000 without any attending gain of any kind. Logic, it would seem to us, should point out that we must give the subject of diabetic gangrene a careful thought when treating this condition. At the risk of being regarded as radical, the writer wishes to reiterate that in his opinion the best form of treatment in ordinary diabetic gangrene (favorable selected cases excepted) both as regards the immediate and end-result, is an early, high, quick, and drained amputation. Past experience has proven this. In those cases surviving operation the average hospital stay was 62.2 days. The average hospital stay of the entire group of 170 cases was 36.5 days.

The writer is in favor of high amputation. Seventy-six per cent. of the cases were mid-thigh amputations. The reasons for this attitude are (1) multiple operations make for increased mortality; (2) it is generally hopeless to amputate a foot or a leg when the arteries immediately above it are hopelessly diseased and incapable of supplying good circula-

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tion; (3) from an economic and functional point of view a thigh stump is preferable. In addition the majority of these patients, because of their advanced years, diabetes and attending complications, rarely do anything in the way of a useful occupation afterwards. Saving them a few inches of extremity, which they will probably never use, at the expense of further operations and increased hospitalization and mortality, seems to be an unwise procedure.

Insulin therapy has been accredited largely with the improved results obtained in the treatment of diabetes and diabetic gangrene. This is possibly only one of several factors which should receive credit. Earlier recognition of diabetes and consequent earlier treatment have improved the status of the diabetic patient immeasurably. This has been brought about by widespread publicity through the radio, newspapers, magazines, health programs, industrial and insurance examinations, and an awakening interest in the public at large in yearly examinations. Because of this the surgeon will see more cases of diabetes in the future demanding his advice. Physicians likewise have been aroused to the benefits of proper dietary régimes and insulin therapy.

All diabetic patients should be warned against infections, cutting corns, calluses, *etc.* Physicians should now be warned against three different things concerning diabetic patients: First, never apply hot wet dressings to gangrenous or infected toes—the poor or absent circulation often results in blisters, infection and moist gangrene; second, never apply ointments to an infected wound in a diabetic—ointments are not necessarily sterile, in fact are most often the reverse—dry dressings and mild dry heat are best in either of the above conditions; third, never fail to call in a surgeon for consultation when infection or possible gangrene threatens.

Many surgeons in the past have erred in the proper medical treatment of surgical diabetics in inadequately caring for their metabolic needs. Now that these patients come to the medical man first and the surgeon only sees the patient when an operation is decided upon, better results should be obtained. Occasionally, the surgeon is called after semisurgical care has been carried out for days or weeks and finds a hopelessly infected case with acidosis. The surgeon and the internist should work hand in hand. Happily, this is the method of treatment at the Philadelphia General Hospital. All patients are admitted to the Metabolic Division and a request for a surgical consultation is immediately answered whenever a condition suggesting surgery appears. The patient is treated pre- and post-operatively in this department where especially trained assistants, a private laboratory and a special diet kitchen are ever waiting to supply his metabolic requirements.

Summary.—A group of 170 diabetic cases operated upon for gangrene has been analyzed. Gangrene affected 13 per cent. of the diabetics in the Philadelphia General Hospital.

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Over 95 per cent. of gangrene was in the lower extremity.

Fifty per cent. of the 170 gangrene cases did not know of their diabetes until gangrene occurred.

Open gangrene with infection is the commonest and gives the poorest results, 87 per cent. of this series.

Infection played a part in 95 per cent. of the fatal cases; *B. welchii* and *streptococci* being the chief offenders.

Early surgery in properly prepared diabetics is essential. Pre-operative insulin, carbohydrates, fluids and perfringens antitoxin are necessary.

High amputations (mid-thigh)—76 per cent. were mid-thigh and single—with drainage in infected cases, gave the best results. Transfixion and guillotine methods were the rule without tourniquet. Spinal anaesthesia was used in 80 per cent. of the cases; local in 17 per cent.

Diabetics with gangrene have had seven years added to their lives by modern method of treatment. Operative mortality (twenty-four hours) was 3.5 per cent.; hospital mortality 41.8 per cent.; one year mortality, 55 per cent., in last sixty-seven cases a slight improvement over the previous series.

Hospital days of the entire 170 was 36.5; of the survivals 62.2 days.

Only 10.4 per cent. of these last sixty-seven cases are alive after eighteen months.

Education of the patient, the physician and the surgeon all working as a team is essential for the best results.

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EMBOLECTOMY FOR ARTERIAL EMBOLISM OF THE EXTREMITIES*

BY HERMAN E. PEARSE, JR., M.D.

OF ROCHESTER, N. Y.

FROM THE DEPARTMENT OF SURGERY, THE UNIVERSITY OF ROCHESTER

THE first successful embolectomy was done by Georges Labey,³ in 1911. Since that time the procedure has had a steadily increasing use. Yet it has not received the recognition that its simplicity and brilliant possibilities warrant. In Sweden the majority of physicians are on the alert to utilize this operation. Elsewhere there exists a general tendency on the part of the medical profession to neglect the procedure. It would appear that many physicians are neither acquainted with the early signs and symptoms of embolism nor are aware of the possibilities to be derived from embolectomy. If this be true then there exists an obligation upon surgeons to acquaint their colleagues with the facts. That these may be readily available the literature has been reviewed and a statistical study made from all reported cases. To these data are added observations from personal experience.

As a direct result of close coöperation among the attending physicians nine early instances of peripheral embolism were seen during the past year. In two of these operation was not done because of serious embolism elsewhere. Seven embolectomies were done in six cases. The results of these were as follows: Two patients died within forty-eight hours from embolism in other regions (result indeterminate); two patients developed gangrene and required amputation; and in three instances the operation was successful.

CASE I.—J. S., SMH No. 24,586. A woman of forty-two years had been treated two years previously by the medical staff for rheumatic heart disease with myocardial insufficiency, mitral stenosis, and auricular fibrillation.

On the day of admission, at 11 A.M., she experienced pain, coldness, numbness and paralysis of the left leg. The pain began just above the knee and soon involved the entire lower leg. Immediate admission to the hospital was obtained. When admitted the left leg was pale and cold below the lower third of the thigh. The foot had the appearance of post-mortem lividity. On the left side the femoral pulse was felt below Poupart's ligament but became imperceptible about one and a half inches below this structure. The left popliteal, posterior tibial and dorsalis pedis pulses were not palpable.

Impression.—Embolism of the common femoral artery, left.

Operation was done under local anæsthesia five hours after onset of symptoms. No embolus was found in the common femoral artery. The superficial femoral was traced down to the middle of Hunter's canal where the obstruction was encountered. Arteriotomy was done and the embolus along with a small distal thrombus was gently milked out. The vessel was empty but did not bleed from its distal portion. A small, well-oiled scoop was passed down the lumen. In the lower popliteal artery another

* Presented before the Rochester Society of Clinical Surgery, November 11, 1932.

embolus was encountered, and removed. There was then brisk back bleeding. Arteriotomy was closed with interrupted silk sutures.

After operation the foot became warm and pink, but in twenty-four hours signs of a failing circulation developed below the knee. This was followed by gangrene which necessitated a mid-thigh amputation.

Dissection of the amputated leg showed a fragment of embolus in the popliteal artery from which an extensive thrombosis had occurred. This case serves to illustrate the uncertainty of indirect, instrumental removal of the embolus.

CASE II.—B. J., SMH No. 47,028. A man of forty years had had two previous hospital admissions. The first was for rheumatic heart disease with mitral stenosis and auricular fibrillation and the second for gangrene of the right foot following embolism. This was treated by a mid-calf amputation.

Three months after his last admission, at 6 P.M., he noticed numbness of the left foot. This was followed in fifteen minutes by pain in the foot and coldness of the foot and calf. He arrived at the hospital one hour after the onset of symptoms.

When admitted, the left foot and lower calf were cadaveric in appearance. It was cold to a definite level of demarcation in the midcalf. There was anaesthesia of the skin of the foot, but pain was elicited by deep pressure. The dorsalis pedis and posterior tibial arteries were pulseless. There was a slight pulsation of the popliteal vessel. It was reasoned that the embolus must be in the popliteal artery at the point of origin of the anterior tibial artery.

Operation, one hour and fifty-five minutes after onset of symptoms, was done under local anaesthesia. The popliteal artery was exposed at the point of bifurcation into its tibial branches, and was normal. The posterior tibial was traced down for approximately two inches. At this point arteriotomy was done and a catheter passed down the vessel. When an obstruction was touched, suction was applied and the catheter was withdrawn. This removed the obstruction so that vigorous back bleeding occurred. The arteriotomy was closed with interrupted mattress sutures.

After operation, though the foot was warm and of good color, the peripheral vessels did not pulsate. All of the obstruction had not been removed. There was gradual failure of the circulation of the foot, gangrene developed and a mid-calf amputation was necessary. Dissection of the vessels of the limb revealed two small emboli lodged in the anterior tibial artery, one eighteen centimetres above the malleolus and another at the beginning of the dorsalis pedis portion. The posterior tibial contained a fragment near its origin. The vascular tree had been obliterated by a propagating thrombosis from these foci of embolism.

The failure in this case is directly attributable to mistaken localization. Rather than one embolus blocking the popliteal artery at its bifurcation, there were small emboli in the peripheral vessels. The removal of multiple, small emboli is very difficult. Their localization is equally disconcerting. It is probable that in this instance visualization by arteriography would have been the only means of identifying the level of obstruction.

CASE III.—R. B., SMH No. 57,383. A woman of forty-seven years was admitted to the hospital with rheumatic heart disease, auricular fibrillation and cerebral embolism. She was drowsy and stuporous but would respond to questioning. She gradually became more alert and responsive so that one week after admission she was considered improved. At noon of the eighth day, she relapsed into an unconscious condition. Examination at this time revealed evidence of cerebral and terminal aortic emboli. Both extremities were cold, cyanotic, and pulseless. The line of demarcation was on a level with the hip-joints. The patient was desperately ill, and would presumably die from the cerebral embolism. This was not certain, however, since she had nearly

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recovered from a similar accident. She was too ill to attempt a transperitoneal approach to the aorta, so it was decided to try the method of Key of retrograde removal through the femoral arteries.

Operation four hours after the embolism. Under local anaesthesia, both femoral arteries were exposed in Scarpa's triangle. The right was opened and an oiled catheter was passed up the vessel until the embolus was encountered. Suction was applied and the catheter withdrawn. Fragments of the embolus were obtained in this way but there was no bleeding from the femoral vessel. After several unsuccessful attempts to dislodge the embolus it was decided that it was too large to remove by this method. The wounds were closed. The patient died the following day. Autopsy showed a large embolus blocking the aorta from the renal branches to its bifurcation.

Comment.—Key² devised the method of removal of an aortic embolus by the femoral approach. A small embolus, insecurely attached at the aortic bifurcation, might be dislodged by this method. In this instance the large size of the mass precluded removal. If the patient's condition permits transperitoneal exposure of the aortic bifurcation then the direct attack is to be preferred.

CASE IV.—E. H., SMH No. 57,341. A man of thirty-six years was admitted to the medical service with a diagnosis of hypertensive heart disease (blood-pressure 175/100) and coronary occlusion. This was confirmed by all clinical and laboratory examinations. There was no evidence of rheumatic myocarditis.

One month after admission, at a time when he was progressing satisfactorily, he experienced pain in the right hand. This was localized to the index and middle fingers. In thirty minutes there was pallor, decreased temperature and diminished sensation of these fingers. The radial pulse was perceptible. One hour after onset he had a pain involving the lower arm with some references to the shoulder. Two hours later, the pallor had involved the hand and forearm to within eight centimetres of the elbow-joint. This area was cold and numb. The radial and ulnar arteries were pulseless.

Diagnosis.—Embolism of brachial artery at its bifurcation.

The patient was operated upon six hours after onset of symptoms under avertin-local anaesthesia. An embolus blocking the brachial artery at its bifurcation was removed.

The following morning the right hand and arm were in good condition, but at 8 A.M. he had severe pain in the left foot and calf of the left leg, which were pale, cold, painful and paralyzed with a line of demarcation about five inches below the knee. The left dorsalis pedis and posterior tibial pulsations were imperceptible while that of the popliteal and femoral were very weak. By means of an arteriogram^{5, 20} the peripheral



FIG. 1.—The accurate localization of the embolus in Case IV by arteriography. The arrow points to the level of the obstruction.

embolus was exactly localized in the posterior tibial artery just below the point of bifurcation of the popliteal. (Fig. 1.) Two hours after the onset of symptoms, the embolus was exposed and removed. The patient recovered with a satisfactory circulation in both the arm and the leg. The X-ray made isolation of the embolus easy. Without it an extensive dissection in search of the point of obstruction would have been necessary.

CASE V.—M. C., SMH No. 65,958. A woman, aged forty-seven, had had diabetes for five years with mild hypertension (blood-pressure 160/84). On the day of admission at 6 A.M., she began to have pain, numbness, coldness and discoloration of her right hand and forearm. These symptoms became progressively worse, and in the afternoon she was seen by her physician, who referred her to hospital for operation. On

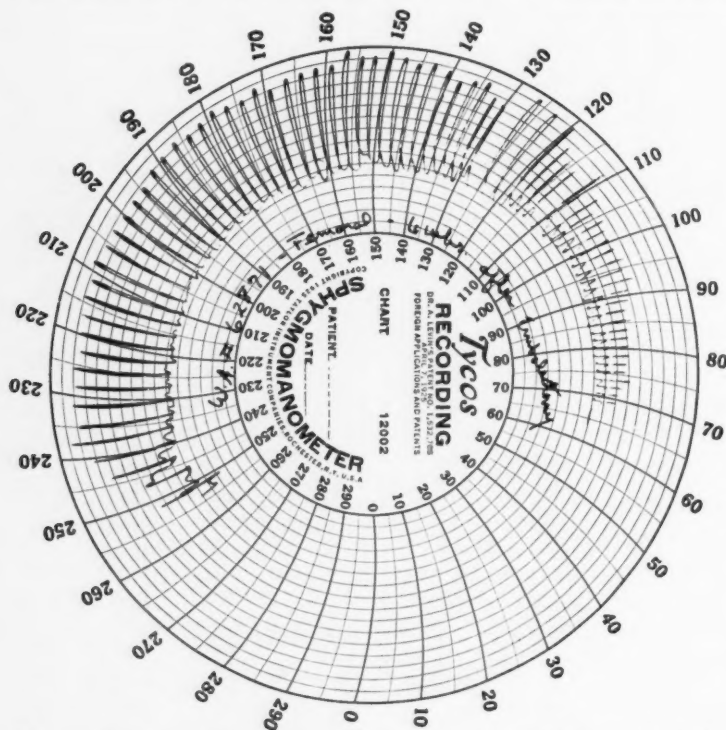


FIG. 2.—The normal pulse tracing distal to the site of embolectomy, six weeks after operation in Case VI.

admission the right hand was cold, numb and blue. The fingers were slightly flexed in a claw-like position. The dark blue cyanosis of the fingers faded to a blotchy, red-dish cyanosis on the forearm. This in turn stopped at a sharp level just below the elbow. The radial and lower brachial pulses were imperceptible but high in the arm near the axilla a pulse was felt. This was confirmed by the recording sphygmomanometer.

The diagnosis rested between embolism and thrombosis of the brachial artery.

Under local anæsthesia, operation was done thirteen hours after onset. The brachial artery was found to be plugged from its origin to its bifurcation. A wide exposure was obtained, an arteriotomy opening was made in the mid-portion of the brachial artery, and the material was gently milked out of the lumen of the vessel. It was not markedly adherent to the vessel wall, nor was there evidence of atheromatous changes. For these reasons the primary lesion was considered to be due to embolism. After removal of the obstruction, brisk bleeding and back-bleeding occurred. On closing the arteriotomy and removing the clamps a strong pulse was seen and felt in the brachial

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and its radial and ulnar branches. At the completion of the operation the radial pulse was perceptible but the hand was still somewhat cold and a little cyanotic.

The following morning the patient developed signs of cerebral embolism and died. Autopsy was refused so the source of the emboli was never determined.

CASE VI.—W. A., SMH No. 62,871. A male, seventy years of age, was admitted to the hospital with acute urinary retention and a perirectal abscess. He was found to have generalized arteriosclerosis with hypertension (blood-pressure 170/100), arteriosclerotic myocarditis, pulmonary emphysema, arthritis, benign prostatic hypertrophy and an ischiorectal abscess.

A suprapubic prostatectomy was done. His convalescence was complicated by intermittent attacks of auricular fibrillation. By his twenty-sixth post-operative day his wound was healed and he was voiding per urethra. A 6 p.m. of this day he complained of tingling, numbness and paralysis of the left lower leg. When examined the foot was mottled by a dusky cyanosis with a very slow return of color after blanching the skin. The limb was cold to the mid-thigh. All vessels were pulseless except the femoral artery just below Poupart's ligament. *Diagnosis.*—Embolism, common femoral artery.

Two and a half hours after the onset, under local anaesthesia, the femoral artery was exposed in Scarpa's triangle. (Dr. W. J. M. Scott.) The embolus was located at the profunda femoris branch. Arteriotomy was done in the common femoral. After extruding the clot brisk back-bleeding occurred from the distal portion. The wound was closed with a running stitch of silk, one interrupted suture being added to control a bleeding point. On removing the clamp proximal to the arterial incision the arterial pulsation was resumed in the superficial femoral, popliteal and pedal arteries. The foot became warm with a normal color. His recovery was uneventful. In Fig. 2 is illustrated the normal restoration of the peripheral pulse.

Comment.—The age of this patient, combined with the presence of hypertension and generalized arteriosclerosis, makes the successful outcome more satisfactory. Arteriosclerosis does not constitute a contra-indication to embolectomy as is well illustrated by the case reported by Keller.²⁸

Literature Review.—The contributions of Carrel to the technic of vascular surgery made embolectomy possible. In turn the work of Key has made of the operation an established surgical procedure. In 1922, he was the first² to review the subject. Then reviews followed by Michaelson,⁴ in 1923, Jefferson,¹ in 1925 and Petitpierre,⁶ in 1928. In a paper published in 1929,² Key collected 226 cases of embolectomy reported up to the end of 1927. To this number I have added seventy cases (including the six here presented) representing seventy-nine embolectomies. This includes all cases published (and catalogued) up to July, 1932, and gives a total of 296 cases reported to date.

Etiology of Embolism of the Peripheral Arteries.—An embolus afloat in the arterial stream has as its origin a thrombus in some part of the vascular system. Usually, the parent thrombus is located in the heart and is consequent to cardiac disease. Mitral stenosis with auricular fibrillation is the most common cause but other abnormalities such as coronary occlusion or vegetative endocarditis may give rise to the primary thrombosis. Conditions such as post-operative thrombosis, arteriosclerosis, infection or aneurism may act as the source. Rarely a phlebitis may give rise to an arterial embolus by means of a patent foramen ovale (paradoxical embolism).

The following tabulation gives the various etiological sources in the group operated upon.

Heart disease	198 cases—60.2 per cent.	Aneurism	5 cases— 1.8 per cent.
Post-operative	37 cases—13 per cent.	Abortion and	
Infection and		delivery	5 cases— 1.8 per cent.
trauma	9 cases— 2.1 per cent.	Miscellaneous	8 cases— 2.8 per cent.
Arteriosclerosis	6 cases— 2.1 per cent.	Phlebitis	1 case — 0.3 per cent.

Age and Sex.—In the group of 296 cases of embolectomy, 133 were males and 163 were females. The age of the members of the group varied considerably. The youngest patient was twelve years while the oldest was eighty-three. The tabulation according to age groups gives the following result.

10-20 years— 4 patients	51-60 years—74 patients
21-30 years—14 patients	61-70 years—63 patients
31-40 years—44 patients	71-80 years—21 patients
41-50 years—66 patients	81-90 years— 3 patients

The Location of Emboli.—Almost without exception embolism occurs at the bifurcation of a vessel or at the origin of one of its large branches. The components of the arterial system have a constantly decreasing calibre as their number increases. There is always a sharp narrowing of the lumen below any bifurcation. This being true, it is obvious how an embolus may float along freely in a main trunk but be unable to enter either branch of a bifurcation. Occasionally, it would appear that an embolus balanced astraddle of the bifurcation rather than being impeded by its disproportionate size. The major divisions of the system occur at the bifurcation of the brachial, aorta, common iliac, common femoral and popliteal arteries. The following tabulation shows these to be the points of greatest incidence of peripheral embolism.

<i>Upper Extremity</i>		<i>Lower Extremity</i>	
Subclavian	2	Aorta	34
Axillary	18	Common Iliac	50
Brachial	40	External Iliac	10
Radial	2	Common Femoral	131
Ulnar	1	Superficial Femoral	11
		Popliteal	33
		Posterior Tibial	3

Some patients had multiple emboli. This accounts for the number of emboli being greater than the number of cases reported.

Diagnosis.—The symptoms of peripheral embolism are very characteristic. They consist of excruciating pain, numbness, coldness and paralysis of the part involved. The pain is of sudden onset. It may start at the site of lodgement of the embolus but soon involves the entire extremity distal to this point. Occasionally pain is a late symptom coming on in forty-five minutes to two hours after the onset. Very rarely it may be mild or absent. The involved extremity is cold, numb and paralyzed. At first the severity of

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the pain may overshadow these sensations. If the pain is delayed then they are the presenting symptoms.

The objective signs of peripheral embolism are pallor, diminished temperature, decreased skin sensitivity, reduced or absent reflexes, and absent pulsation in the peripheral arteries. The color change which begins as a waxy, cadaveric pallor gradually shifts to a dark blue cyanosis in the distal part. Proximal to this there is a blotchy discoloration not unlike post-mortem lividity. In the late stages the hand or foot becomes shrunken, contracted or even mummified.

These symptoms and signs give a clear-cut picture denoting sudden ischemia. This is rarely confused with other vascular lesions, either venous or arterial. Occasionally the differentiation from spontaneous arterial thrombosis may cause trouble. Here the fact that thrombosis is usually preceded by symptoms of arterial disease gives some assistance. Moreover, the symptoms from thrombosis are apt to be more gradual in onset with slowly developing, less severe pain.

Localization.—The exact localization of the embolus is of extreme importance to the success of embolectomy. If the clot can be freely exposed and completely removed under direct vision then the object of the operation has been accomplished. If, on the other hand, it is not found where expected, two courses are open. The first is to dissect out the artery in search of the embolus. This may necessitate an extensive dissection and even sacrifice of important structures. The second alternative is to open the artery and by means of a catheter, curette, screw-probe or forceps attempt the removal of the embolus. This intravascular manipulation may cause damage to the intima with thrombus formation. Or, this blind attempt may result in incomplete removal with a fragment of the embolus remaining to act as a focus for thrombosis. In either event the purpose of the operation is defeated.

The embolus may be located in a number of ways. The point of predilection for embolism has been shown to be at the major bifurcations of the peripheral arteries. Obstruction at any point causes obliteration of the distal pulses as well as a characteristic level of ischemia. These facts combined with a knowledge of anatomy gives a fairly accurate idea of the location of the embolus. The level of ischemia is usually from four to eight inches below the embolus. Thus obstruction of the aorta or common iliac gives a level near Poupart's ligament, that of the common femoral near mid-thigh, of the superficial femoral near the knee and of the popliteal near the mid-calf. If embolectomy is not done the line of demarcation of gangrene is always more distal than the primary level of ischemia. Occasionally the embolus can be felt as a hard lump. If this is the case a more forceful pulsation is palpable at the site of or just proximal to the swelling.

The information obtained from physical examination should serve to localize emboli in the larger vessels. In the more peripheral locations x-ray localization by arteriography may be used (Case IV). Loewe²⁶ has also

reported a case where this means was employed. Though I have sponsored a method of arteriography,⁵ I am well aware that any foreign substance injected into an artery has the potentiality of doing harm. Yet if there is doubt about the location of the embolus the danger of its incomplete removal is felt to be greater than the risk from arteriography.

Operative Technic.—The anaesthesia of choice for embolectomy is local infiltration or regional block. This was used in over 70 per cent. of the reported cases. The primary condition causing the embolus usually results in the patient being a poor anaesthetic risk. Local anaesthesia may be used in all except aortic or iliac embolism. Here the transperitoneal approach requires general or spinal anaesthesia. If the patient's condition will not tolerate this anaesthetic burden then the retrograde removal through the femoral arteries (Key) may be tried. In fifty cases of aortic or common iliac embolism, direct removal gave 30 per cent. good results as against 25 per cent. for the indirect method. In all other instances intravascular probing with any instrument is to be condemned. No matter how gently it is done the intima may be sufficiently damaged to cause thrombosis.

The essential factor in the technic is to remove the embolus with minimum damage to the artery. This demands the utmost delicacy and gentleness in the manipulation. Dehydration is avoided by keeping the field covered with mineral oil or with 2 per cent. sodium citrate. All instruments, sutures and needles are likewise oiled before use. The artery should be exposed enough to allow its isolation above and below the embolus. After exposure the vessel is compressed by oiled, rubber-shod "bull-dog" clamps at points well away from the embolus. Crile clamps or even a tape may be used for this purpose. The adventitia is carefully cut away from the prepared site of the arteriotomy. (Fig. 3.) The artery is opened just above (or below) the embolus for a distance of one to two centimeters. (Fig. 4.) The lumen is moistened with oil or with a 2 per cent. sodium citrate solution. If it is desired to hold open the edges of the arteriotomy, sutures may be put obliquely through the wall. (Fig. 4-a.) The opening may be handled by iris forceps or Bernheim's ball-tipped forceps. In general, it is wise to refrain from unnecessary handling of the wound. By means of gentle milking of the vessel the embolus is expressed from the lumen. (Fig. 5.) Small fragments may be picked out with forceps without touching the intima. Momentary release of the proximal clamp flushes out the upper part of the channel. The distal clamp is then temporarily removed to assure the presence of back-bleeding. Following this the lumen is washed free of blood with warm Ringer's solution and oil applied. If back-bleeding is sluggish or absent from the distal portions some authors pass a probe, curette or catheter to attempt removal of the obstructing thrombus. It would appear that the manoeuvre of Lund²⁵ is preferable. This consists of exposure of the vessel at a point distal to the arteriotomy, and, after puncture with a needle, retrograde flushing with normal saline or Ringer's solution. This serves to wash out through the arteriotomy any thrombotic masses.

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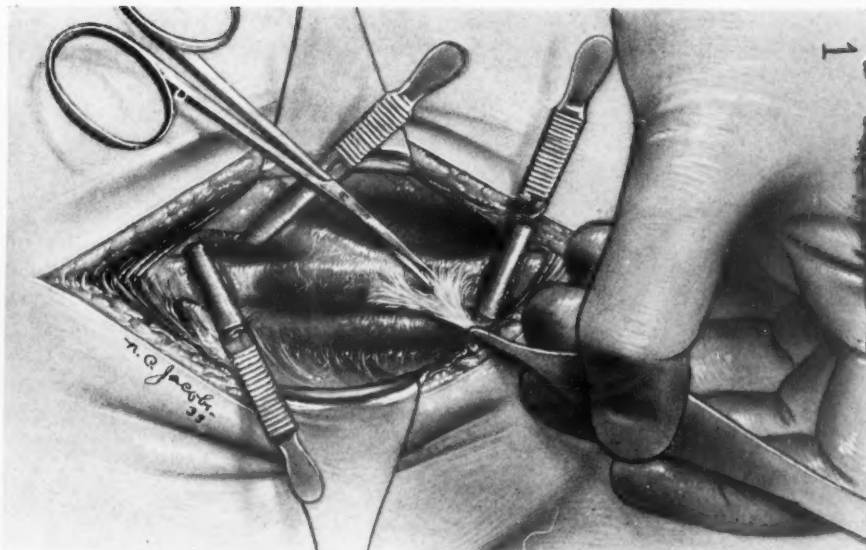


FIG. 3.

FIG. 3.—After locating the embolus the adventitia is picked up and carefully cut away from the proposed site of the arteriotomy. If this is not done strands of adventitia may be drawn into the lumen during suture and cause thrombosis. The opening in the artery is made just above (or below) the embolus. Insert "a" shows how traction sutures may be placed into but not through the vessel wall.

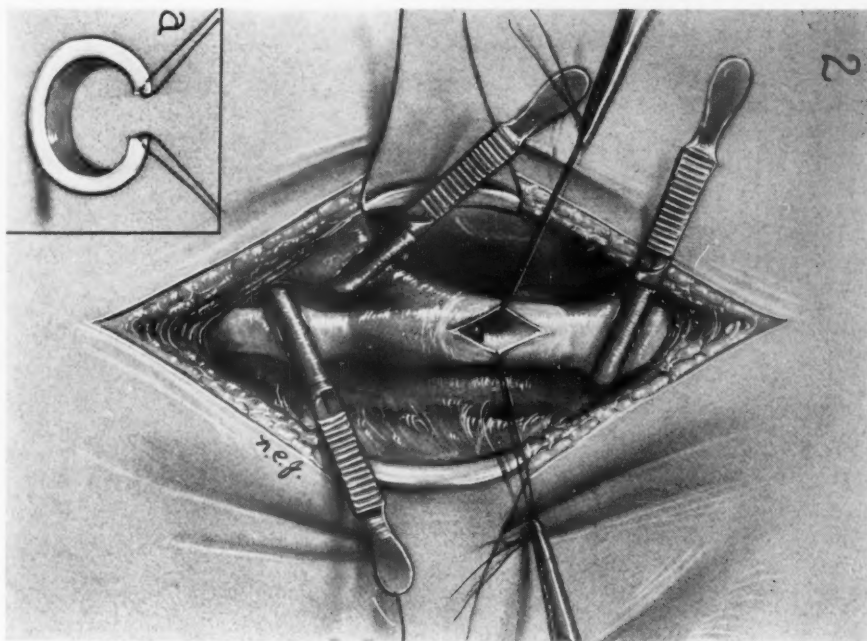


FIG. 4.

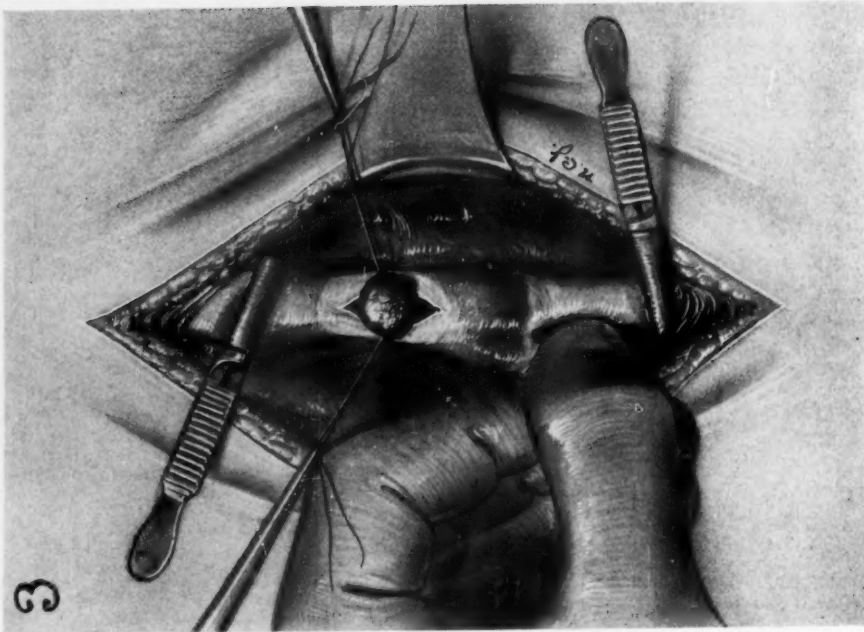


FIG. 5.

FIG. 5.—The embolus is extruded by gentle compression of the artery. After removal of the embolus all fragments should be carefully flushed out. FIG. 6.—The arteriotomy wound is sutured with a continuous Carrell stitch of delicate silk. A wider approximation of the intima is obtained by interrupted mattress sutures. (Insert "b".) After completion of the closure the distal clamps are removed before the proximal one in order to avoid undue strain on the suture line.

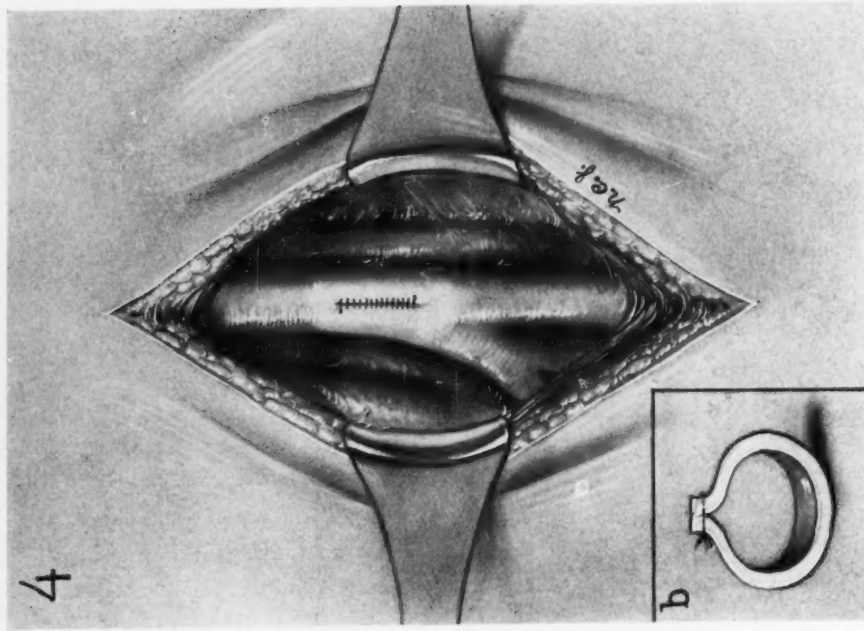


FIG. 6.

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After removal of all foreign material the arteriotomy is sutured. For this purpose either the continuous Carrell stitch (Fig. 6) or interrupted mattress (Halsted) sutures (Fig. 6-b) may be used. Carrell needles threaded with split silk, well oiled, are best. Arterial sutures of delicate silk on Carrell needles are also available commercially. The stitches should be closely spaced with an even tension on the suture to approximate intima to intima. At the completion of the closure the distal and then the proximal clamps are removed. A moment's pressure with a sponge serves to stop all oozing. Occasionally an additional stitch is needed to control a bleeding point. Some surgeons place a second suture line outside the primary closure. This is unnecessary.

TABLE I
Results of 282 Embolectomies

	1-5 hours		5-10 hours		10 Hr. Summary	10-15- hrs.		15-20 hrs.		20-30 hrs.		30-48 hrs.		over 48		Total	
LOCATION	Cases	Good	Cases	Good	Good	Cases	Good	Cases	Good	Cases	Good	Cases	Good	Cases	Good	Cases	Good
Subclavian	1	1	1	0	50%*											2	1
Axillary	8	4	3	1	45%	2	1	3	1	1	1	1	1			18	9
Brachial	9	4	10	5	47%	2	1			2	0	1	0	2	0	26	10
Aorta	14	4	5	2	31%	2	0	1	0	6	1	3	0			31	7
Common Iliac	14	3	14	6	38%	3	0	3	0	4	0	3	1	1	0	42	10
External Iliac	4	3	1	1	80%*									1	0	6	4
Common Femoral	44	18	25	11	45%	23	2	11	1	7	0	7	0			117	32
Superficial Femoral	4	1	1	0	20%	1	0			3	0					9	1
Popliteal	11	4	10	3	32%	3	2	1	0	1	0	2	0			28	9
Posterior Tibial	3	2			66%*											3	2
Total Number	112	44	70	29		36	6	19	2	24	2	17	2	4	0	282	85
Total Per Cent		39%		41%	40%		16%		10%		8%						

*The small number of cases makes this unreliable.

I have had on two occasions the opportunity of studying arteriotomy wounds treated in this matter. Both showed a very thin layer of coagulum less than one millimetre wide sealing the wound. The lumen was patent without evidence of reaction or thrombosis on the intimal surface.

Results.—Before evaluating the effect of embolectomy, one must first define what is considered a good result. This is necessary since some cases have temporary improvement for a few days after which ischemia and gangrene develop. Others have a satisfactory restoration of the circulation but die some time after operation either from their original disease or from embolism elsewhere. These results are certainly not successful. To exclude them an arbitrary interval of one month was selected as adequate to assure the permanency of the outcome. Consequently a good result is defined as one

in which embolectomy restores a competent circulation for more than a month.

The results of 282 embolectomies are given in Table I. These results are tabulated according to the location of the embolus and the time elapsing between embolism and operation. The information about a few additional cases was inadequate to include them in this tabulation.

Two important facts appear from these data. The first is the great importance of early operation. There is very little difference between the results of the first two five-hour periods. Combined they have an average of 40 per cent. success. But after ten hours the results become progressively poorer. The average of the second ten-hour period shows 14 per cent. and of the third ten-hour period 8 per cent. good results. After an interval of forty-eight hours it is not worth doing the operation since no successful cases have been reported after this time. It is probable that two factors contribute to failure after the first ten hours. The first is the formation of a thrombus which obliterates the vascular channels distal to the embolus. This thrombosis may be present only a few hours after the embolism. The second factor is the damage to the intima caused by the continued presence of the embolus. This is slight at first but progressively increases so that even after a careful embolectomy a thrombus reforms at the site of embolism. These factors cannot be satisfactorily combated. They can be avoided only by early operation. Thus embolectomy is one of the most urgent of surgical emergencies.

The second fact revealed by the tabulation of results is the influence of the location of the embolus on the outcome. A summary of the per cent. of successes is given for the first ten-hour period. From this it is seen that in the more superficial arteries (axillary, brachial, and common femoral) the results are better than for those in a deeper location. If the results for the first ten hours are computed for regions it is found that in the upper extremity 47 per cent., in the lower extremity 40 per cent., and in the pelvis (aorta and common iliac) 31 per cent. are satisfactory.

Over half of the patients subjected to embolectomy died within a month of operation. Of the 282 cases shown in the table 149 died (52 per cent.) within this time. Death was caused either by their systemic disease or by embolism to vital structures. The embolectomy played very little part in producing the lethal effect. This is shown by the fact that only 9 per cent. of the group died within a day of the operation. Of these only one died on the table. Many of the remainder are stated to have died from embolism elsewhere. It is probable that the risk of embolectomy done under local anaesthesia is negligible. This risk is materially increased by the burden of a spinal or general anaesthesia.

In the tabulated group, 122 patients survived for twenty-four hours but died within a month of operation. Of these, thirty-five or 12 per cent. had a satisfactory circulation in the extremity operated upon. Of this number twenty-eight or 10 per cent. had the embolus removed within ten hours.

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This percentage (10 per cent.) may be added to that of the permanent good results (40 per cent.) to show the relative effectiveness of embolectomy in restoring the circulation.

Result of Procedure Other than Embolectomy.—There are several other methods of treating peripheral embolism which require discussion.

Conservative Measures.—Under this heading are grouped those procedures employed when a course of "watchful waiting" is decided upon. They consist of general supportive measures as well as local treatment. This latter consists of rest, elevation and the application of heat. If gangrene occurs amputation is delayed until a line of demarcation forms. There is no doubt that embolism of a major artery will result in gangrene and loss of limb in the majority of instances. Thus, these conservative measures have now been superseded by embolectomy in all early cases. In those seen late the conservative attitude is still justifiable.

Massage.—Lindstrom is the foremost advocate of massage in the treatment of embolism of the extremities. By massage an effort is made to break up or dislodge the embolus and force it down into the smaller branches of the arterial system. This may leave enough channels uninvolved to assure collateral circulation. On the other hand, the manipulation may forcibly impact parts of the embolus into necessary arterial segments. Because of its uncertainty massage has little appeal when contrasted to early, complete removal of the embolus by arteriotomy. But the results in a few cases are not bad. In twelve of twenty instances of embolism gangrene was avoided. Key collected eighteen of these in sixteen patients. Mason²⁹ has recorded a case and we have seen one case in this clinic. This latter patient apparently had embolic occlusion of the popliteal artery. By his forceful massage the embolus was pushed into the anterior tibial branch. The patient recovered without gangrene but the functional capacity of the limb was slight. This result is not uncommon for though gangrene is avoided yet a part of the arterial system is occluded.

Vein Ligation.—Therapeutic venous obstruction has been applied in the treatment of embolism under two circumstances. Its first use is as an addition to conservative treatment. It is difficult to evaluate the effect here but it certainly is not a substitute for embolectomy. We have had experience with three cases. All of these were seen too late for operative removal of the embolus. In two, slight improvement occurred, but in the third no change was noted and gangrene developed. Vein ligation is no panacea. It deserves consideration only in the late case which is on the verge of circulatory failure. Under such conditions its use would appear justifiable.

The other circumstances where vein ligation has been used is as an adjunct to embolectomy. Some authors tied the vein after removal of the embolus. The reasoning applied is apparently that the benefit of the vein ligation is derived in case the embolectomy fails. I have never done this. Perhaps it is justifiable but I have felt that all efforts should be directed towards careful complete removal of the embolus. This is the important

issue. In case this fails then it is a simple matter to reopen the wound and ligate the vein. This was done in Case II. It did not make a particle of difference, as far as could be observed, in the outcome.

Arteriotomy.—The excision of the artery with its contained embolus and thrombus has been advocated. The basis for this is the lower incidence of gangrene from ligation than from embolism at the same level. If the thrombotic process subsequent to embolism can be kept from plugging the distal arteries, then collateral circulation may save the limb. This is not an unreasonable hypothesis. Its application will depend upon the known incidence of gangrene from ligation of the particular artery involved. It should not be considered as a substitute for embolectomy in favorable cases. But in those seen late, it might be used with benefit.

SUMMARY

(1) The operation of embolectomy deserves a wider use. This may be brought about if surgeons interested in the subject acquaint their colleagues with the possibilities of the procedure.

(2) As a direct result of close coöperation with the attending physician nine early instances of embolism of the extremities were seen within the past year. Two of these were not operated upon because of serious embolism elsewhere. Seven embolectomies were done in six cases. Of these two died, two developed gangrene and three were successful. These cases are reported.

(3) 296 cases of embolectomy have been recorded in the literature up to July, 1932. A study of all reported cases has been made.

(4) It was found that the embolus came from a primary heart disease in 69.2 per cent. and from post-operative states in 13 per cent. of the cases. Various etiological conditions accounted for the remainder.

(5) Almost without exception the embolus lodges at a major bifurcation of the arteries of the extremity. The most common locations are at the division of the common femoral, common iliac, brachial, aorta and popliteal arteries.

(6) The symptoms of embolism of the extremity are excruciating pain, numbness, coldness and paralysis of the part involved. The signs consist of pallor, diminished temperature, decreased skin sensitivity, reduced or absent reflexes and absent pulsation in the peripheral arteries.

(7) The pre-operative localization of the embolus and the operative technic are discussed.

(8) Aside from the careful technic, the results from embolectomy are shown to be dependent upon exact localization and early complete removal of the embolus. Operation within ten hours gives 40 per cent. successful results. Delay mitigates against a favorable outcome.

(9) Over half (52 per cent.) of the patients subjected to embolectomy died within a month of operation. This materially lowers the per cent. of good results from the operative procedure. Yet the embolectomy usually

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plays no part in the lethal result. The high mortality is due either to the primary systemic disease or to embolism to vital structures.

(10) In embolism of the arteries of the extremity the ideal to be achieved is early, complete removal of the embolus with restoration of the continuity of the circulation.

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THE TRENDELENBURG OPERATION FOR PULMONARY EMBOLISM

BY RETTIG ARNOLD GRISWOLD, M.D.

OF LOUISVILLE, KY.

FROM THE DEPARTMENT OF SURGERY OF THE LAKESIDE HOSPITAL AND THE WESTERN RESERVE UNIVERSITY SCHOOL OF MEDICINE, CLEVELAND, OHIO

SINCE Kirschner,¹ in 1924, reported his successful operation for pulmonary embolism, there has been a marked increase in the number of such operations performed in European clinics. The chief contributions in this field have been by Meyer,² Nyström,³ Giertz and Crafoord,⁴ and Crafoord,⁵ and they have made important modifications of the original operation devised by Trendelenburg,⁶ in 1908. It is remarkable that no attempts have been reported from American clinics. Matas⁷ has said: "It is hoped that the teachers in charge of the schools of operative and experimental surgery will take heed of this notable advance and make the practice of embolectomy and of the Trendelenburg operation an obligate part of the curriculum in the laboratories of experimental surgery." Willy Meyer and Lilienthal⁸ recommended intensive training of the hospital staff in this procedure.

Two unsuccessful cases are reported here with the feeling that since we frequently learn more from our mistakes than from our successes these lessons should be passed on. It is difficult to evaluate a comparatively unproven procedure such as this unless all cases are described in detail. It is only in this way that the diagnosis, the indications, and the technic may be clarified and perfected, and the unsuccessful as well as the successful cases will determine whether pulmonary embolectomy will be generally accepted or will be found unworthy and discarded.

The incidence, occurrence and etiology of pulmonary embolism have been adequately discussed in recent literature. The papers of Petré,⁹ Hosoi,¹⁰ and Giertz and Crafoord⁴ are outstanding. Hosoi¹⁰ states that the incidence varies from 0.12 to 0.67 per cent., as reported by various authors. Harvey¹¹ states that massive pulmonary embolism is fatal in about one-half of 1 per cent. of all cases operated upon, and that in operative procedures in the lower abdomen the mortality from this cause rises to two per hundred, a seemingly irreducible minimum, composing about one-quarter of fatalities from all causes. He considers that operative removal of the embolus from the pulmonary artery is impracticable and that it is more important to devise methods to prevent the occurrence of an embolus. An irreducible minimum of 2 per cent. in lower abdominal operations, however, should lead the surgeon to restorative as well as to preventive efforts. Some authors believe that the condition is becoming increasingly frequent, but this may be apparent only because of better diagnosis.

The diagnosis may be self-evident or it may be difficult. The usual syn-

drome is sudden collapse, pallor, lividity of lips and nails, loss of pulse and rapid difficult respiration. Substernal pain and the sensation of impending death may be present. Cyanosis and unconsciousness may ensue before death. In the series of Giertz and Crafoord,⁴ the most frequent symptoms in twenty-three cases were:

<i>Sudden onset of symptoms without any forewarning</i>	23 cases
High, soft, finally imperceptible pulse.....	23 cases
Marked pallor	18 cases
Unconsciousness	17 cases
Livid lips, slight cyanosis.....	12 cases
Altered respiration	23 cases
Anginoid pain	20 cases

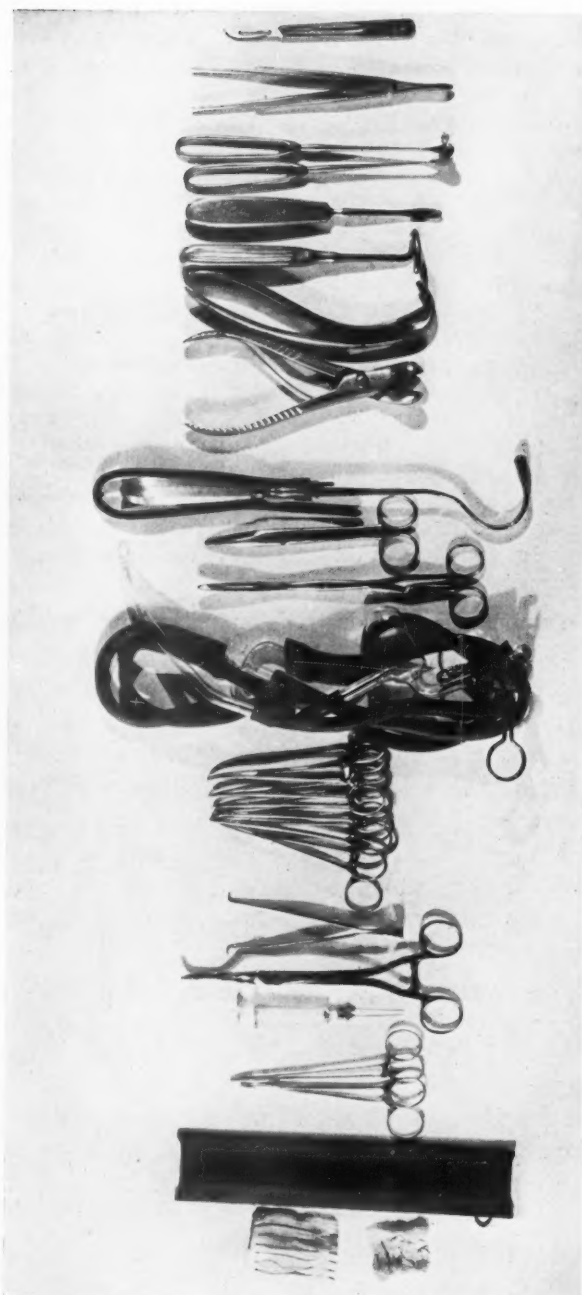
The limited time is the chief obstacle to diagnosis. Other conditions may mimic pulmonary embolism. Nyström³ operated upon a patient dying from uræmia and cites other cases in which the diagnosis was incorrect. The following case illustrates such a mistake in diagnosis. This patient had all the symptoms tabulated above except anginoid pain.

F. H. a white male of forty-three years, had a badly swollen and infected amputation stump of the left thigh. The temperature had been as high as 39.7° C., but on the fourth and fifth days post-operative it did not rise above 38.2° C. The pulse rate ranged between 90 and 120, with respirations of 20. His condition seemed satisfactory and though the stump was very œdematous it was draining well. He was somewhat restless the afternoon of the fifth day but stated that he felt well except for some pain in the stump. When he finished his evening meal at 5:30 P.M. the nurse noted that he seemed to be in good condition. At 5:40 he called her, was moaning and said that he was going to die. His skin was ashen and mottled, the nails were cyanotic, the respirations were labored, 34 per minute, and his pulse was very weak with a rate of 144. When I saw him fifteen minutes later the pulse and respirations were the same. Systolic blood-pressure was obtained at 70 with no clear diastolic. He complained of no pain but still had the sensation of impending death. The hands and nails were cyanotic; the skin elsewhere was pallid and moist.

He was taken immediately to the operating room and prepared for the Trendelenburg operation and for ligation of the left common iliac artery. The pulse became imperceptible, the heart rate being about 150 by stethoscope, with very weak heart sound. The systolic beat was obtained at 35. Respirations became more labored, cyanosis was marked and the patient became unconscious.

Incision for the Trendelenburg operation was made at 6:30 without reaction on the part of the patient, no anæsthetic being necessary. A left parasternal incision was made from the upper border of the second costal cartilage to the lower border of the fourth, carried through the skin, subcutaneous tissue and pectoralis major muscle exposing the costal cartilages. The soft parts were retracted laterally, the Doyen rasp was introduced around and beneath the third costal cartilage close to the sternum, and the intercostal muscles were pushed laterally, according to the method of Meyer, striking a cleavage plane outside the pleura. A section of costal cartilage, two inches in length, was rapidly removed and a similar procedure was carried out on the fourth and second costal cartilages. About one-third the width of the sternum was removed with a large rongeur. This exposed the pleura and the pericardium. The heart could be seen beating fairly well so that it was possible to proceed slowly and carefully from this point onward. A finger was introduced downward into the triangle of safety and the finger swept upward, pushing the pleura away from the pericardium to the upper limit of the wound.

Fig. 1.—Instruments for Trendelenburg operation arranged in order of use reading from left to right: 1—Scalpel. 2—Two pairs of thumb forceps. 3—Two rake retractors. 4—Peritoneal elevator. 5—Doyen raspatory. 6—Kib. shears. 7—Large bone rongeurs. 8—Trendelenburg-Nystrom sound with clip and catheter attached. 9—Scissors. 10—Trendelenburg forceps for removing emboli. 11—Nystrom's suction tips. 12—Hemostats. 13—Footed thumb forceps for holding slit in artery. 14—Artery clip. 15—Syringe and needle for adrenalin. 16—Needle holders. 17—Fine silk on a board. 18—Curved needles. 19—Threaded straight needles for skin.



This was accomplished very easily without injuring the pleura. The pericardium was picked up and incised from the lower angle of the wound well up toward the base of the heart. The thymus, which overlay the upper portion of the pericardium, was damaged during this procedure. The pericardial cavity was smooth and glistening and contained probably ten cubic centimetres of pale, straw-colored fluid. The heart was beating feebly, about 120 per minute. The Trendelenburg sound was introduced through the great transverse sinus, the rubber tube attached and drawn around the aorta and pulmonary artery, bringing them up into the wound. A longitudinal incision, 15 centimetres long, was made in the pulmonary artery just distal to the valve. The operation from the time of incision to this point had taken approximately 190 seconds. Trendelenburg forceps were introduced into the pulmonary artery and the two main branches on both right and left sides easily found. No embolus was withdrawn or felt. The flow of blood from the pulmonary artery was good on relaxation of the tube. The heart beat had become more feeble; the tube was, therefore, relaxed and the opening in the artery held with the fingers to allow the heart to recover somewhat. There was slight improvement in the heart action after the application of hot saline solution, massage and the injection of one cubic centimetre of adrenalin into the right auricle. The tube was again tightened and the arteries were re-explored, the upper and lower branches on both sides being again entered without finding a clot. The heart action was becoming more and more feeble and did not respond to a second injection of adrenalin into the left ventricle or to adrenalin dropped on the surface. The anæsthetist had reported increasing cyanosis and more labored respiration, and blood coming from the pulmonary artery was quite dark. Respirations ceased at 6:43. The heart was delivered out of the wound. It was flabby, anæmic and soft, but no lesions of the coronary vessels could be demonstrated.

Autopsy was not obtained.

It is a common idea that death from pulmonary embolus is almost immediate. Trendelenburg⁶ realized the incorrectness of this conception and observed that in at least one-half the cases a minimum of fifteen minutes would be at the disposal of the surgeon. Giertz and Crafoord⁴ found that of twenty-seven cases of pulmonary embolism the diagnosis was not established until after death in four instances. Three cases were operated upon, with two recoveries. Of the remaining twenty, they feel that thirteen cases would have been possible cases for operation and that in another four the operative possibility was open to question.

In the twenty cases the time from onset of attack until death was as follows:

Less than ten minutes.....	3
Ten to twenty minutes.....	7
Twenty minutes to one hour.....	4
Over one hour.....	6

We have for the past year kept a set of sterilized instruments in the operating room for the Trendelenburg operation. They are arranged in a pocketed roll in the order of use from left to right. (Figs. 1 and 2.) The house staff and head nurses have been taught the cardinal signs of embolism and there are at most times surgeons within easy reach who are capable of performing the operation.

The *technic* has been practiced on cadavers and is remarkably easy to master. We have used a combination of the methods and instruments of Nyström and Meyer, as modified from Trendelenburg. A straight incision is made along the left side of the

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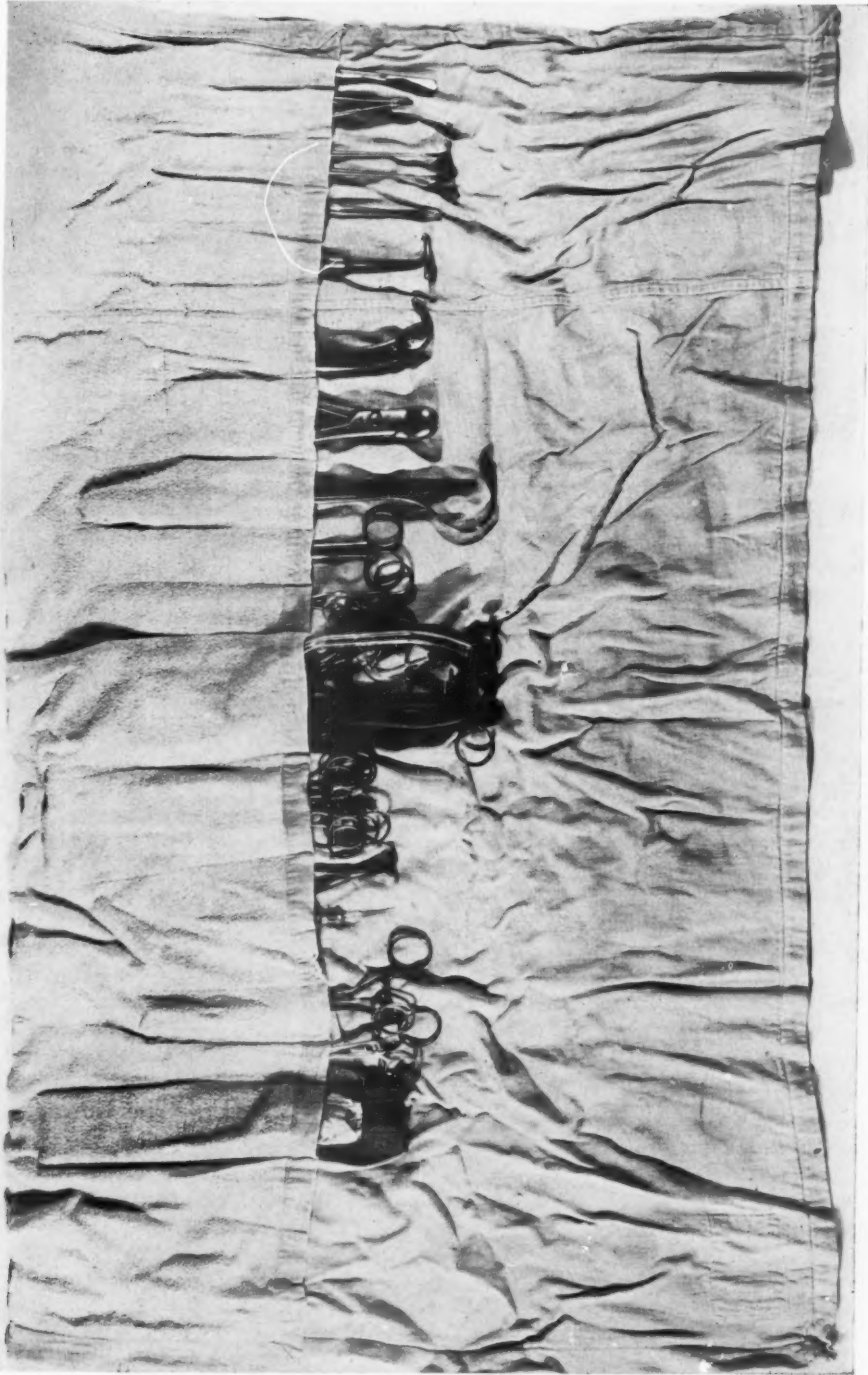


FIG. 2.—Instruments are kept in a sterilized roll and are handed out in order from left to right.

sternum from the upper border of the second to the lower border of the fourth costal cartilages, dividing the origin of the pectoralis major. A Doyen raspatory is passed about the third cartilage close to the sternum and pushed sharply to the left according to the method of Meyer.² This strips the soft tissues from the rib and enables one to do a rapid resection without injuring the pleura or internal mammary artery as the instrument invariably enters the proper plane of cleavage if correctly inserted. This is easier, quicker and safer than the usual subperiosteal resection. The second and fourth cartilages with a bit of rib are similarly resected and from one-fourth to one-third the width of the sternum is removed with large rongeurs. The forefinger is inserted at the lower angle of the wound into the triangle of safety of Voinitch-Sianojentyzky and swept cephalad, easily stripping the pleura laterally from the pericardium. The pericardium is picked up and opened with knife or scissors. The opening may be enlarged by the fingers or by cutting. In the latter case there is some chance of injuring the thymus.

Nyström's Trendelenburg sound is passed from left to right through the great transverse sinus behind the aorta and pulmonary artery, the rubber tube with its clip attached to the sound and drawn back. Gentle traction on the tube lifts these vessels from the depths of the wound. The pulmonary artery is usually easily identified, although the aorta has been opened by mistake.³ The longitudinal incision in the artery should be placed with care to avoid injury to the orifice of the valve. An incision of 1.5 centimetres is sufficient. The rubber tube is relaxed to allow clots in the heart to be flooded out, then the tube is tightened and the blood is rapidly removed from the pericardium. Gentle traction is important as there have been instances of trauma from the tube being pulled too tightly. It is sufficient to use just enough traction for exposure as the hemostatic effect is probably unnecessary.

With the Trendelenburg forceps the pulmonary branches are explored, first on one side and then on the other. The right main branch extends toward the right axilla and the left directly backward and there is usually little difficulty in finding them. If the emboli are soft and friable the suction tips of Nyström⁴ may be useful, but the clot usually comes out in two or three large pieces. If difficulty and delay are experienced at this point it is a good plan to compress the slit in the vessel with the fingers and relax the traction tube to allow the heart to recover somewhat before making another attempt at extraction, as suggested by Trendelenburg.⁵ It is stated⁶ that forty-five seconds is the limit of time during which the pulmonary artery may be completely compressed. This is open to question, however, and Nyström³ believes that under favorable circumstances complete suspension of the circulation for nearly two minutes may not be incompatible with life. If the suction tip has been used, the vessel should be flooded with blood to drive out air before closure. The slit in the vessel is held up by "footed" thumb forceps, the artery clamp applied, and the lips of the incision closed with a continuous fine silk suture. If necessary, the clamp may be left on while any necessary resuscitating measures are taken, such as cardiac massage, intracardiac injection of adrenalin or artificial respiration, before suturing the vessel. An opening should be left in the pericardium to prevent tamponade from accumulation of fluid.

In the following case all the elements necessary for success were present, namely, an otherwise healthy patient, correct diagnosis, abundance of time, proper equipment, and an adequately trained team of operator, assistants, nurses and anæsthetist. The operation was delayed too long, however, in the hope that recovery might ensue without operation. A less conservative course should have led to success.

E. Z., a white married woman of twenty-four years. Her past history was irrelevant except for three normal pregnancies and a gynecological procedure in August, 1931. At that time a perineorrhaphy, uterine suspension, and appendectomy were performed. The post-operative course was uneventful. A history of gall-bladder disease began about

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three years ago with attacks of sharp epigastric pain after meals. This pain radiated through to the back and lasted about twenty minutes. It was sometimes partially relieved by food or soda. She had had typical biliary-tract indigestion. Attacks continued at shorter intervals and for the two weeks before admission had occurred daily, lasting eight to ten hours. The patient had never been jaundiced or noticed clay-colored stools.

The physical examination showed a well-nourished and well-developed female of twenty-four years, whose heart was slightly enlarged to the left with a soft systolic murmur, heard best at apical and aortic regions. The head, neck, throat and lungs were normal. The abdomen was rounded, and there was a small tender mass palpable at the tip of the ninth right costal cartilage. The liver did not seem to be enlarged. There were no other masses, tenderness or muscle spasm in the abdomen. A healed mid-line lower abdominal scar was present. The pelvic and rectal examinations and examination of the reflexes and extremities showed nothing remarkable. In the cholecystogram there were multiple negative shadows diagnostic of calculi. On admission the temperature was 38.2° C., pulse 110, blood-pressure 110/80, respirations 20. The urine was normal except for an occasional white blood-cell. The white blood-cell count was 13,600. The hæmoglobin was 60 per cent.

May 27, 1932, cholecystectomy was carried out through the usual right paramedian incision. The gall-bladder was pale, œdematous, thick-walled and adherent. It contained cloudy, pale gray fluid which showed no organisms on culture. The pathological report on the gall-bladder was acute cholecystitis and cholelithiasis. There was nothing unusual about the conditions found at operation. The cystic duct and cystic artery were ligated separately, the gall-bladder bed was closed and the operative field drained by two cigarette drains. The immediate post-operative condition was good. The temperature went as high as 39.6° C., with a pulse of 120 following operation, but gradually came down in the course of five days to 37.5° C. The pulse came down to 80 and the respirations ranged between 20 and 24. Her bowels moved on the third day. The fluid intake ranged from 2,150 cubic centimetres to 3,700 cubic centimetres. The white blood count dropped to 7,200 on the fourth day. The sutures were removed on the fifth day. The wound was in good condition and there was no undue tenderness or spasm of the abdomen. There had been no swelling or pain in either leg.

At 8:00 P.M. on the fifth day the temperature was 37.5° C., pulse 80, respirations 20. At 10:30 P.M. the patient awakened suddenly, sat up in bed and complained of extreme shortness of breath. The pulse was weak, and respirations extremely rapid. She was seen by the interne at about 10:40. The pulse at that time was 140 and almost imperceptible. The blood-pressure was 70/60 and respirations 40. I saw her at 11:10. At this time the skin was cold and clammy, the face pallid, lips and finger-nails somewhat cyanotic and respirations rapid and labored. The blood-pressure was 80/60. The pulse remained almost imperceptible. Cardiac rate by stethoscope was about 140. The sounds were clear and strong and there was a good cardiac impulse palpable. The costal margins moved equally, and no shift of the mediastinum could be made out. The lungs were clear anteriorly and laterally, posterior examination not being carried out. Nothing remarkable was found in the abdomen. There was no swelling of either lower extremity and no tenderness along the course of the great veins. A diagnosis of pulmonary embolus was made.

The patient was taken immediately to the surgical floor and placed in a preparation room. Her only complaint was of extreme difficulty with respiration. She stated that she had no pain and did not feel a sense of impending disaster. On account of dyspnoea and cyanosis of lips and nails, inhalation of oxygen was started through an anæsthetic mask. This brought considerable relief. Observations of pulse, respirations and blood-pressure were taken at intervals of five minutes from this time on. There was very little variation in these readings. Respiration ranged from 48 to 60, cardiac rate from 106 to 140, blood-pressure from 80/70 to 98/80. Her skin became warm and dry. The temperature at 2:00 A.M. was 39.2° C., at 5:00 A.M. 39.8° C. Her clinical condition

showed little change except that as the night wore on she demanded increasing quantities of oxygen. At first oxygen could be left off for several moments with little discomfort. After 3:00 A.M., however, continuous administration of large quantities was necessary. At about 4:00 A.M. she complained of pain in the chest anteriorly in the mid-line, and an hour later localized this in her heart. Cardiac impulse continued to be forceful as determined by palpation and auscultation. She had been seen by members of the Medical Service at 1:00 A.M. and they agreed with the diagnosis of pulmonary embolus. At 6:00 A.M. a portable X-ray plate of the chest was taken which showed an indefinite shadow of density at the right base running into the hilus. The lower half of the left chest contained a shadow of even density which, however, was not dense enough for pneumonia. At about 6:00 o'clock the blood-pressure apparatus was changed from the left arm to the right because of pain and numbness from the continued application. The blood-pressure was imperceptible from this time on. Cardiac rate was 130, respirations 50 to 60. The cardiac impulse was good, although the peripheral pulse was imperceptible. The patient had been entirely conscious, oriented and coöperative throughout the night. At 6:30 A.M. one-sixth grain of morphine was given for pain. At 7:00 A.M. respirations suddenly ceased, cardiac impulse could not be heard or felt, and the pupils became widely dilated.

The equipment and the personnel for the Trendelenburg operation had been kept in readiness during this time. The patient was hurriedly wheeled in bed across the hall



FIG. 3.—Emboli removed from Case II. The longer clot was from the left pulmonary branches and the shorter clot from the right.

into the operating room, scrubbed and draped, and an incision was made along the left border of the sternum, from the upper margin of the second costal cartilage to the lower margin of the fourth. The lateral edge of the incision was retracted and the second, third and fourth costal cartilages with muscles were removed according to the method of Meyer. The heart was immobile. The left pleura was reflected laterally by placing the finger in the triangle of safety and sweeping upward and to the left. This was accomplished easily without tearing the pleura. The pericardium was picked up, incised and the incision spread with the fingers for a distance of about eight centimetres. The heart remained motionless and no respirations occurred. Meanwhile, carbon dioxide and oxygen were being given rhythmically under pressure. The Trendelenburg sound was passed through the great transverse sinus from left to right, the aorta and pulmonary artery drawn forward with a rubber tube, and the pulmonary artery opened by a longitudinal incision 1.5 centimetres in length just distal to the valve. There was a gush of dark blood from the opening. The Trendelenburg forceps inserted into the right main branches brought forth one cylindrical clot which later was found to measure 12.5 centimetres in length and 7 millimetres in diameter (maximum); from the left main branches a clot twenty-eight centimetres by eight millimetres was obtained. (Fig. 3.) The opening in the vessel was temporarily closed by grasping it with the fingers. The rubber tube was released and the heart massaged. Regular cardiac contractions of fairly good strength resulted. The entire time from the cessation of respiration and

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cardiac action was something less than ten minutes, the time from the skin incision less than three minutes. The pulmonary artery and aorta were lifted by the rubber tube for perhaps forty seconds. Fairly well maintained contractions having been obtained, the opening in the pulmonary artery was secured with the Trendelenburg clip. The heart beat had been fairly forceful and the tone of the cardiac muscle seemed comparatively good. The beat, however, became weaker and finally ceased. Contractions were restored by massage, and the intracardiac injection of adrenalin together with the application of hot saline solution to the surface of the heart. This procedure was gone through with several times until cardiac contraction finally ceased at 8:15 A.M. Artificial respiration and carbon dioxide oxygen therapy had been continued during this time. The opening in the pulmonary artery was closed with a continuous, fine silk suture at about 8 o'clock. This closure was not quite tight and leaked blood with each contraction of the heart so that a second single reinforcing suture was placed. The myocardium had become progressively weaker, both in regard to strength of contraction and interval tone, the heart finally stopping in a state of complete dilatation and relaxation. Permission for autopsy was not obtained.

Failure of the Trendelenburg operation in this case, which should have been ideally favorable for the procedure, was, I believe, due to the fact that oxygen was administered over a long period of time, improving the clinical appearance and masking the true condition of the patient until the overburdened right heart had lost all recuperative power after pumping against an almost completely obstructed pulmonary system for over eight hours. Operation was not carried out earlier because the patient's unchanged appearance led me to believe that she might recover spontaneously. If oxygen had not been administered her apparent condition would have become so bad that we would have been forced to operate shortly after the onset. I cannot help but feel that operation undertaken before her myocardium and respiratory centres had become exhausted would have been successful.

SUMMARY AND CONCLUSIONS

(1) Two unsuccessful cases of pulmonary embolectomy are reported. The first case illustrates some difficulties of diagnosis; the second the results of a too conservative attitude.

(2) This procedure, if carefully studied as to diagnosis, indications and technic, is the only hope of saving quite a large class of patients, since prophylactic measures directed against the incidence of pulmonary embolism have so far shown themselves of no avail.

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ADVANCES IN THE DIAGNOSIS AND TREATMENT OF THROMBO-ANGIITIS OBLITERANS

BY SAMUEL PERLOW, M.D.

OF CHICAGO, ILL.

FROM THE PERIPHERAL CIRCULATORY CLINIC OF THE MICHAEL REESE HOSPITAL

UNTIL recent years, thrombo-angiitis obliterans has been a relatively obscure disease and its differentiation from other types of peripheral vascular disturbances was difficult. Its treatment was chaotic, and amputation of the extremity was resorted to very early in its course. With the advent of a better understanding of the pathology of this disease and modern methods in its diagnosis, the treatment was placed on a firmer physiological basis.

The condition was first described by von Winiwarter,¹ in 1879. Buerger,² in 1908, was the first to interpret accurately its pathology as an inflammatory condition involving the arteries and deep veins of the extremities and resulting in thrombus formation. As the acute inflammation subsides and the condition becomes chronic, the thrombi become organized and canalized. He suggested the term thrombo-angiitis obliterans as a descriptive name for the disease. Since then nothing new has been added to our knowledge of the pathology except that the disease is not confined to the vessels of the extremities but is a generalized condition. Cases of thrombo-angiitis obliterans involving the vessels of the heart,³ brain,⁴ and gastro-intestinal tract⁵ have been reported.

The etiology of thrombo-angiitis obliterans is still obscure. Although a large proportion of the cases occur in Russian and Polish Jews, the condition is not confined to that race and has been found in Japanese, Norwegians, Germans, Swedes and even in Negroes. It is a disease of young men and is rare in females. Buerger⁶ believes that it is an infectious process. In his experiments, the paravascular implantation of clots from cases of acute thrombo-angiitis obliterans was followed by the development of typical lesions in the apparently healthy ligated veins of the inoculated persons. Rabinowitz⁷ found a Gram-negative motile bacillus in a small number of cases. Horton and Dorsey⁸ obtained a Gram-positive pleomorphic streptococcus in nine cases and a green-producing streptococcus in two cases. Their results after injecting these organisms into rabbits were inconclusive.

It is generally believed that the use of tobacco is a factor in thrombo-angiitis obliterans. Just how important it is cannot be stated, but Barker,⁹ of The Mayo Clinic, who studied the records of 350 cases of thrombo-angiitis obliterans and of 350 controls, believes that nicotine predisposes to recurrences. According to Silbert,¹⁰ "Whatever the underlying cause, prolonged smoking is the immediate causative factor in the production of the disease." Willy Meyer¹¹ believes that sufficient amounts of nicotine, pyridin, cyanic hydrogen, carbon monoxide and other poisons are contained in tobacco

smoke to cause secondary vascular changes. However, Jablons and Koyano have reported the condition in non-smokers. The tobacco factor must be carefully evaluated as occasionally smoking is initiated and often accentuated when the patient experiences pain and cannot sleep.

Diagnosis.—The symptom complex of intermittent claudication, coldness of the toes and feet, trophic changes in the skin and nails and beginning gangrene of the extremities in a man between the ages of twenty and forty-five years is very suggestive of thrombo-angiitis obliterans.

The disease is frequently preceded by a migrating phlebitis of the superficial veins of one or both lower extremities. By some clinicians this finding is considered pathognomonic of the disease. It is followed, usually in several months, but sometimes in several years, by the insidious development of cramp-like pain in the arches and soles of the feet and in the lower parts of the legs during cold weather and on walking moderate distances. The patient soon finds that the pain disappears when he is at rest with the feet pendent. These symptoms resemble closely those of fallen arches, and occasionally cases are treated for some time on that basis or for so-called rheumatism before the true condition is recognized. The extremities become cold and the pain becomes more severe and more frequent. It is present after walking shorter and shorter distances and assumes the typical character of intermittent claudication. Finally, the patient has severe and sometimes lancinating pain in the extremities even while at rest. About 95 per cent. of the cases have symptoms referable to the lower extremities. Although in about 30 per cent. of the cases there is involvement of the vessels of the upper extremities, which is found on examination, the patients seldom have symptoms in those limbs. Sometimes a chronic ulcer on a poorly healing infection of a toe dating from an injury or from the removal of a toenail is the only complaint which brings the patient to the physician.

As the condition advances, parts of the extremities finally become cyanotic and gangrenous, first the toes and then the feet. However, the disease does not always become progressively worse, but spontaneous remissions occur. They may last for months and even years, and frequently a sufficient collateral circulation is established to cause a complete cessation of the symptoms.

On examination in the early cases one usually finds only a slight cyanosis and coldness of one or more toes. In the later stages the feet and sometimes the leg may be cold and the cyanosis may involve the whole foot. It is often patchy and may vary from pink to deep purple. Samuels¹² has recently called attention to the almost constant presence of plantar ischaemia in thrombo-angiitis obliterans. There may be present trophic changes as abnormally large callosities and linear breaks in the skin and a marked thickening of the nails of the toes. Pulsations in the arteries are usually present in the early stages, but as the condition progresses the dorsalis pedis and the posterior tibial arteries cease to pulsate, and in the late stages one cannot feel even the popliteal arteries. The gangrene which one finds in the very last stages is usually a dry type frequently involving the skin of one or more toes.

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As it advances the deeper structures and finally the foot and the leg become affected. Preceding the gangrene there is always an area of deep cyanosis and hard oedema.

Buerger¹³ describes a simple test which is a great aid in the diagnosis and differentiation from other conditions. With the patient in the supine position, elevation of the extremity 45° to 90° , in cases of thrombo-angiitis obliterans, results in a marked ischæmia in thirty seconds to three minutes which may involve several toes or parts of the foot or leg. Lowering the extremity 45° to 90° below horizontal results in a marked reactionary rubor in the same areas. Buerger explains the latter phenomenon as a reflex dilatation of the capillaries of the skin after being emptied on elevation due to the inability of the collateral circulation to force blood up against gravity. This reaction is present to a lesser degree in arteriosclerosis of the vessels of the lower limbs. In early cases this is a particularly valuable sign for it may be present long before the chronic cyanosis develops.

Another valuable aid in diagnosis brought out by Buerger is the angle of circulatory sufficiency. "The estimation of the angle of circulatory sufficiency is based on the supposition that the normal limb, when elevated so as to be perpendicular to the horizontal plane, that is 180° , still retains most of its color. When the circulatory mechanism is defective, and the limb is elevated to the vertical, a variable degree of blanching of the foot occurs. If the leg is then gradually depressed, *the angle at which a reddish hue returns* (angle of circulatory sufficiency) will be found to vary considerably. In some cases it will be necessary to depress the limb to the horizontal before evidences of return circulation are manifest. The angle of circulatory sufficiency would then be 90° . If the reestablishment of visible circulation in the skin necessitates depression below the horizontal, the angle will be correspondingly less than 90° . In many cases of arterial disease, the estimation of this angle is a valuable adjuvant, not only in the recognition of the extent of the circulatory disturbance, but also in the prognosis."¹³ In thrombo-angiitis obliterans the angle of circulatory sufficiency is seldom above 90° and most often is about 60° .

Brown, Allen and Mahorner,¹⁴ in a report based on the study of over 300 cases at The Mayo Clinic, state that a careful analysis of the symptoms and the ordinary clinical findings are sufficient to make a diagnosis in about 95 per cent. of the cases. However, a description of the recent advances in the instrumental and other aids in the diagnosis and prognosis of thrombo-angiitis obliterans lies within the scope of this review.

Variations of the surface temperature usually occur in vascular diseases of the extremities. This can be determined roughly by palpation with the palm of the hand, but more accurate temperature determinations may be made by means of the thermocouple galvanometer or by means of the skin thermometer which is more practical and accurate enough for ordinary purposes. Normally the temperature of the skin in a room at 22° to 26° C. varies from 33° to 35° C. in the region of the thigh to 30° or 32° C. at the

toes. Variations of several degrees in either direction may frequently be found. In thrombo-angiitis obliterans there is usually a general lowering of the temperature of the skin with a marked drop at the point where very poor circulation begins. It is not a very reliable diagnostic sign, however, because the temperature is determined by the circulation in the skin and is independent of the deep circulation, and it may vary considerably in any one individual. It is very useful in comparative studies to determine the effects of vasodilating agents.

The oscillometer was first used in the study of peripheral vascular disturbances by Pachon¹⁵ in 1909. It is an instrument which measures the maximal and minimal arterial pressures and the oscillations of the pressure in the arteries. It consists essentially of a rubber bag armlet which is connected to a manometer and to an anaëroid chamber which measures the rhythmic variations in the volume of that segment of the limb to which it is applied. This is transmitted to a needle which oscillates over a graduated scale. Its use has become widespread in the quantitative diagnosis of peripheral vascular disease and in the differentiation between organic and vascular disturbances. Normally there is a gradual drop in the oscillometer readings taken from the thigh down to the foot or from the arm to the hand. A sudden or too acute drop in the readings denotes vascular occlusion. In a functional vascular occlusion the degree of oscillation will return to normal when the spasm is relieved by immersing the extremity in a hot bath for fifteen to thirty minutes. The oscillometer cannot differentiate accurately between thrombo-angiitis obliterans and other organic vascular occlusive conditions as arteriosclerosis. According to Samuels¹⁶ its value lies in (1) the detection of minute changes in the sum total of pulsations; (2) determination of changes in volume flow in regions in which the arteries are not accessible to the palpating fingers as in the region of the calf; (3) an accurate quantitative method for comparison of the condition of circulation during various phases of treatment or for comparison with other extremities, and (4) a valuable adjunct in the differential diagnosis of vasomotor and occlusive vascular disease.

Cohen¹⁷ in 1924 was the first to use the intracutaneous salt solution test in the diagnosis of peripheral vascular disturbances. Normally it takes from thirty to sixty minutes for an intradermal wheal of physiological salt solution to become absorbed. In cases of vascular occlusion the absorption of the salt solution and the disappearance of the wheal take place very rapidly due to the lowered fluid content of the tissues. The height on the extremity and the degree of rapidity of the abnormally rapid absorption denote the height and the degree of vascular occlusion.

Thomas Lewis¹⁸ in 1927, following the original observations of Ep-pinger¹⁹ in 1913, demonstrated that the histamine reaction consisted of three distinct factors: (1) A local dilatation of the capillaries, venules and arterioles by direct action, which caused a purplish spot to appear; (2) a widespread dilatation of the surrounding arterioles by local reflex action,

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which was visible as a red flare; and (3) a local increase in the permeability of the walls of the minute vessels by direct action, which caused a wheal at the site of injection. He also demonstrated that if the circulation was completely cut off only a purple spot would form but no wheal or flare, and that coldness of the skin retarded the reaction. Starr²⁰ on that basis used this reaction in the study of peripheral vascular disturbances by the method of pricking the skin a number of times through a drop of histamine. He found that normally the skin reaction to histamine is at its height in two and one-half to five minutes and that the changes suggesting a reduction in circulation are (1) delay in appearance of the reaction; (2) delay in appearance plus a reduction in the intensity of the reaction; (3) failure of either flare or wheal to appear; (4) failure of both the flare and wheal to appear and the reaction to consist of only a purple spot which was a sign of complete obstruction.

The histamine test as now performed by de Takáts²¹ consists of the intradermal injection of 0.1 cubic centimetres of 1:1000 histamine solution (ergamine acid phosphate). The reactions are the same as those described by Starr. The wheal is irregular but sharply defined and is usually $\frac{1}{2}$ to 1 cubic centimetre in diameter. The flare surrounding it is also irregular but not raised and extends for 1 to 2 centimetres in each direction. The test is fairly accurate as a means of determination of circulatory efficiency and agrees closely with the oscillometric readings and the surface temperature as determined by the skin thermometer. Besides diminution in circulation, other factors which cause a delayed reaction are degeneration of cutaneous nerves, previous use of histamine at the same spot, injury of the skin by ultraviolet and X-rays or burns, and various skin diseases.

Treatment.—In treating cases of thrombo-angiitis obliterans, one must understand that the symptoms of which the patient complains are not due to the disease proper but to nature's method of healing the condition with its resultant vascular occlusion. One must also remember that there is a constant race between the obliteration of the vessels and the formation of a collateral circulation, and that the outcome is determined by the relative speed of the two processes. There is no proved specific treatment of thrombo-angiitis obliterans. It is purely that of aiding the formation of a collateral circulation and in symptomatic relief. In general, the treatment can be divided into (1) the removal of factors which may predispose to recurrences, and (2) measures to increase the circulation and relieve the pain.

The use of tobacco on the part of the patient with thrombo-angiitis obliterans is prohibited in most clinics. As has been stated before, although the exact relation that tobacco has to the disease is not known, it has been definitely established in numerous series of cases^{9, 10} that patients who stop smoking improve much faster and more completely than those who do not.

Recently Kaunitz,²² in a study of ergotism, found that there is a definite similarity in the symptoms and pathology between chronic endemic ergotism and thrombo-angiitis obliterans. Russian and Polish Jews as a rule eat large

quantities of rye bread, which has been shown to contain considerable ergot. Whether ergot is a causative factor in thrombo-angiitis obliterans and whether the effect of the ergot-containing rye bread upon the peripheral circulation is great enough to warrant elimination of that food from the diet is still a mooted question. Kaunitz advised prophylaxis and the elimination of as much ergot as possible from the foods.

Bed rest and heat to the extremity are among the simplest and most effective methods used to promote the formation of a collateral circulation. The period of rest should be from three to six weeks or more and should be accompanied by the application of dry heat for two hours several times daily. Diathermy and quartz-light treatment have their indication—the former to warm the extremity and by the relief of vascular spasm and vasodilatation to aid in the formation of a collateral circulation, and the latter to stimulate healing of superficial, slowly healing ulcers.

Buerger¹³ devised a set of exercises which have been found to stimulate considerably the reestablishment of circulation. With the patient lying on his back the extremity is elevated 60° to 90° above horizontal for the minimum time required to produce ischæmia (thirty seconds to three minutes). It is then allowed to hang down until one minute after the appearance of the reactionary rubor (two minutes to five minutes). The extremity is then held in the horizontal position for three to five minutes, during which time dry heat in the form of a therapeutic lamp is applied. This cycle is repeated for one hour every alternating hour of the day.

Contrast foot baths aid greatly in the formation of a collateral circulation by means of the alternate contraction and dilatation of the vessels. The baths consist in alternately immersing the extremity for one-half to one minute in cold water at 40° to 50° F. and warm water at 100° to 110° F. This should be continued for fifteen to thirty minutes several times daily and may follow the exercises described before.

Ever since the discovery by Mayesima in 1915 that in thrombo-angiitis obliterans there is an increase in the blood viscosity, methods of treatment have been devised to combat this effect. The ingestion of large quantities of fluids, as Ringer's solution, Locke's solution, physiological salt solution and various concentrations of sodium citrate, has been tried. The solutions have been taken by mouth, by duodenal tube, by rectum, subcutaneously and intravenously with varying and on the whole poor results. Recently Silbert²³ at Mt. Sinai Hospital in New York instituted the intravenous injection of 5 per cent. sodium chloride solution in a large number of cases with apparently excellent results. He cites a series of 460 untreated cases in which 64 per cent. required amputation within five years of the onset of the disease and 46 per cent. required two amputations within ten years of the onset. In a group of 225 cases treated by the intravenous injection of 5 per cent. sodium chloride solution amputation was required in only 8.3 per cent. There was symptomatic improvement in 84 per cent., and 67 per cent. returned to work with complete relief from the symptoms. At the first

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injection only 150 cubic centimetres of the solution are given to determine the sensitivity of the patient. Following this 300 cubic centimetres are given three times weekly for about a month and then gradually reduced. Improvement is usually noticed in several weeks. After the treatment has been stopped it may be necessary to repeat the courses at various intervals. Silbert believes that the improvement is due to a stretching of the vascular tree and to a dilution of the blood. This treatment is contraindicated in patients over sixty years of age and in those who show signs of an injured myocardium or poor renal function. It has been used with success in the treatment of gangrene in thrombo-angiitis obliterans by Samuels,²⁴ who reports excellent results with relief of the pain and ultimate auto-amputation, and sometimes an intact extremity.

Foreign protein therapy in occlusive vascular conditions of the extremities was first described by Goodman and Gottesman²⁵ in 1923, who used this method for the relief of pain in cases of thrombo-angiitis obliterans, after noting its effect in cases of chronic arthritis. Since then, numerous cases have been reported with excellent results in promoting the formation of a collateral circulation and relief of pain. The method of treatment consists in the intravenous injection of typhoid vaccine. Twenty-five million bacteria are given at the first injection and increased 15,000,000 to 25,000,000 at each succeeding dose. Doses of 500,000,000 bacteria have been given intravenously without deleterious effects. The injection of the vaccine is usually best given at intervals of four to five days but may be given daily if desired.

The reaction consists of three definite stages, a prodromal period, a stage of decrease in capillary flow and a stage of vasodilatation. The prodromal stage lasts from one-half to one hour and during this time the patient is perfectly comfortable. The second stage is usually initiated by a chill. The general body temperature rises, but there is a peripheral vasoconstriction and a drop in the skin temperature of the extremity. The patient may experience sharp pain in the involved extremities during this stage which may last from several minutes to an hour or more. Following this is the stage of vasodilatation. The general body temperature may continue to rise another degree or two, the extremities begin to feel warm, and the surface temperature may rise three to four degrees and sometimes as high as ten degrees above the starting temperature. This stage usually lasts six to ten hours.

This type of treatment is contraindicated in patients with heart or kidney disease, hypertension, and those in a debilitated condition. Occasionally it is possible to do harm if the stage of peripheral vasoconstriction is prolonged, especially in extremities on the verge of gangrene.

To eliminate some of the disagreeable effects of the chill and to shorten or eliminate the stage of vasoconstriction a typhoid "H" vaccine has been developed.²⁶ "It is a fraction of typhoid bacteria. After the organisms have been emulsified in sodium chloride solution they are killed with 0.5 per cent. phenol, which for the most part blocks the other component, the 'O' antigen, and also acts as a preservative. The 'O' antigen is a non-specific

antigen which is a fraction of many different bacteria. Typhoid 'H' antigen is thermo labile but keeps satisfactorily at room temperatures. Its action is not inhibited by phenol or formaldehyde. It is destroyed by alcohol. It is apparently a specific antigen for typhoid bacteria." Barker²⁶ reports a series of cases comparing the effects of the ordinary typhoid vaccine (T.A.B.) and typhoid "H" vaccine. With the former, 75 per cent. of the patients had a chill. With the latter, only 27 per cent. of the patients developed a chill. The vasodilatory effects were similar.

Waller and Allen²⁷ report the use of a 2 per cent. sulphur suspension in oil injected intramuscularly to induce fever in cases of peripheral vascular disease, with varying results.

Various operative procedures have been designed to increase the vascularity of the diseased extremities. Artificial arteriovenous anastomosis was found to be feasible in normal experimental animals but has been unsuccessful in diseased human beings; first, because the vessels are thickened and contracted, and second, because the veins are also involved in the diseased process. High ligation of the main arteries has been tried and successful cases reported.²⁸ However, a clear understanding of the pathology in thrombo-angiitis obliterans will demonstrate the obvious impossibility of improving the circulation by such a procedure. Van Gorder²⁹ reports a series of nine cases in which he ligated the main vein with very excellent results. He bases his method of treatment on the supposition that a restriction of the outflow of blood from the limb by ligation of the main vein will counterbalance the diminished blood supply due to the diseased artery. Horton,³⁰ Holman,³¹ Brooks,³² and Pearse,³³ have demonstrated that ligation of the popliteal vein in cases of thrombo-angiitis obliterans and arteriosclerotic gangrene results in an elevation of the temperature of the extremity. This is apparently due to an increase in the residual arterial pressure, in the venous pressure, and in the peripheral arterial circulatory bed.

The researches on the periarterial sympathetics by René Leriche in 1921³⁴ and a report on the successful treatment of various types of trophic disturbances, painful stumps, and causalgia by periarterial sympathectomy in 1924, stimulated the study of the relation of the sympathetic system to peripheral circulatory disturbances. Many series of cases have been treated by the resection of the periarterial sympathetics but with very poor results. A. W. Allen,³⁵ in a study of the end-results of such an operation in occlusive vascular disease of the extremities, states that "periarterial sympathectomy has a very limited field. It is undoubtedly followed by a temporary hyperemia which is more effective than that produced by electrical or mechanical measures and will aid in the healing of ulceration. It must be remembered, however, that the cases benefited by it will probably heal with a longer period of palliative treatment." An adequate explanation for the failure of periarterial sympathectomy in peripheral circulatory diseases is the demonstration by Potts³⁶ that the sympathetic nerve supply for the vessels of the lower extremities reaches the main vessels at intervals along their course from the neigh-

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boring nerves. Thus, stripping the femoral artery will not remove the sympathetic supply of its divisions lower down.

Royle in 1924³⁷ in his studies on the relief of spastic disturbances of the lower extremities observed that there was an increase in the warmth of the extremity on the side operated upon. Following this observation the operation of lumbar sympathetic ramisectomy and ganglionectomy was performed in Raynaud's disease and in occlusive vascular diseases of the extremity with excellent results.^{38, 39, 40} The basis for this operation in thrombo-angiitis obliterans is the fact that in that condition there is both vascular occlusion and vascular spasm. E. V. Allen³⁹ believes that impulses originating in the vessels are carried to the spinal cord and then are reflexly expressed as vasoconstriction. Cutting the lumbar sympathetic chains breaks the reflex arc and allows vasodilatation. It is not curative in occlusive vascular disease, but it allows the limb a maximum amount of blood. This operative procedure is useful only in cases in which there is a definite vascular spasm. This can be determined by the vasomotor index of Brown,⁴¹ which is determined in the following manner: Fever is induced with intravenous typhoid vaccine and the increase in surface temperature of the limb measured at one-half-hour intervals with a thermocouple galvanometer or skin thermometer. The vasomotor index = $\frac{\text{Rise in temperature} - \text{rise in mouth temperature}}{\text{Rise in mouth temperature}}$. In

normal individuals the rise in surface temperature of the toes is greater than the rise in mouth temperature. Unless indices of 1.5 or more are obtained, Brown does not advise an operation on the lumbar sympathetics. Other methods for the selection of patients for this operation are the paravertebral block of the sympathetics with procaine⁴² and the blocking of the peripheral nerves.⁴³ In both methods there is a rise in the surface temperature if there is a vascular spasm accompanying the occlusion of the vessel. In spite of the enthusiastic reports in the literature, however, Samuels²⁴ believes that the operation is too severe for the results obtained. Leriche⁴⁴ believes that no sympathetic operation is of value in thrombo-angiitis obliterans. He believes that for the operation to do good there must be a partially intact peripheral circulatory system.

Recently there have been reports^{45, 46} of excellent results obtained in the treatment of Raynaud's disease and thrombo-angiitis obliterans by irradiation of the lumbar sympathetic ganglia by the use of a very strong current.

The relief of pain in thrombo-angiitis obliterans goes along with the improvement in the general condition by the methods described above. However, in the pregangrenous stage, when the pain is intolerable or when there is a large ulcer which causes extreme pain, other and more direct methods are necessary. Silbert⁴⁷ and Smithwick and White⁴⁸ isolate the nerve supplying sensory fibres to the painful area and inject it with alcohol. This causes a complete anaesthesia of that area for three to six months and has been found to aid greatly in cases having painful, slowly healing ulcers, allowing thorough Dakinization and removal of the necrotic tissue. Because of the slow healing

of the operative wound due to the poor circulation, the nerves should be isolated above the ankle in all cases.

Various other forms of therapy have been advised in thrombo-angiitis obliterans. Bæcke⁴⁹ in 1927 reported the successful outcome of a case after treatment with ovarian extract. He bases his treatment upon the teachings of Marshak who believes that in thrombo-angiitis obliterans there is a hypersecretion of the suprarenal glands and that this is neutralized by ovarian extracts. He offers as proof of this hypothesis, the almost complete absence of the disease in females. Based on similar conclusions other European surgeons advocated suprarenalectomy.⁵⁰ However, Herzberg⁵¹ in a survey of 120 cases treated by suprarenalectomy states that although the immediate results are good the majority of the cases finally required amputation. Schwartzman⁵² reported good results in forty-two cases treated by the daily injection of muscle extract on the basis that the extract acts as a powerful depressor and overcomes vascular spasm.

Gangrene of the extremity is the much-dreaded final stage in thrombo-angiitis obliterans. Its treatment is usually amputation, although ultra-conservatism is advocated even in that stage by most authors. However, if amputation has to be resorted to finally, it should always be done above the point of deficient circulation, which should be determined by the use of the oscillometer and by the rise in surface temperature after typhoid injections.

In summarizing the recent advances in thrombo-angiitis obliterans, we see that its diagnosis does not mean that the patient is doomed to go through life on artificial legs, that the prognosis is not utterly hopeless and that the keynote of present-day treatment is conservatism.

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RELIEF OF PAIN BY PERIPHERAL NERVE SECTION

By NORMAN F. LASKEY, M.D., AND SAMUEL SILBERT, M.D.

OF NEW YORK, N. Y.

FROM THE OUT-PATIENT DEPARTMENT OF THE MOUNT SINAI HOSPITAL

PAIN is an early and important symptom in thrombo-angiitis obliterans. It may be due to the migrating phlebitis which occurs in the early stage of the disease. Local infection of the foot with tenosynovitis or abscess formation occasionally produces severe pain. More frequently, however, pain is the result of anoxemia of the distal tissues induced by arterial thrombosis. Lesions secondary to this, such as fissures, ulcerations or gangrene, may be responsible for the most violent forms of pain observed in this disease.

Relief of pain in thrombo-angiitis obliterans is of primary importance, and the success of conservative treatment depends upon it. Continuous severe pain often results in destroying the patient's morale by interfering with his sleep. Even the generous use of narcotics is insufficient to give relief in some instances.

The tendency in the treatment of this disease has been towards conservatism, and the results in the past few years have justified this attitude. Patients with ulcers or local gangrene formerly came to early amputation, in many cases due to the fact that severe pain could not be relieved. On account of the extreme sensitiveness of the ulcerated areas it was practically impossible, in the average patient, to dress or Dakinize these wounds satisfactorily. Attempts to relieve pain by the use of anæsthetic ointments are harmful in our opinion, inasmuch as these medicaments destroy tissue and tend to increase ulceration.

In 1922, one of us,¹ was the first to report a series of four cases in which the posterior tibial nerve was blocked with alcohol for the relief of pain in thrombo-angiitis obliterans. All four patients had complete relief, though in one case the foot became gangrenous and in another the wound healed slowly. In 1929, Corlette² reported a method of cutting the terminal sensory nerves by a subcutaneous transverse incision above the painful ulcers of the malleolus. Smithwick and White,³ in 1930, reported eleven cases in which the sensory nerves of the leg were injected with alcohol. Relief of pain was accomplished in all. In November, 1932, Allen⁴ summarized the results from the same clinic, reporting a total of twenty-nine cases.

Recently we have decided that simple section of the nerve with immediate suture is superior to alcohol injection. The objections to the latter method are twofold. (1) It is impossible to be assured in employing alcohol injections that some of the nerve fibres may not be missed and result in persistence of some of the pain. (2) There is also the possible danger of producing ulcers from the inadvertent spilling or seeping of alcohol into tissues.

In carrying out the technic of nerve section the anatomical distribution of the nerves supplying the foot as well as their function must be clearly borne in mind. There are only five nerves which supply sensation to the

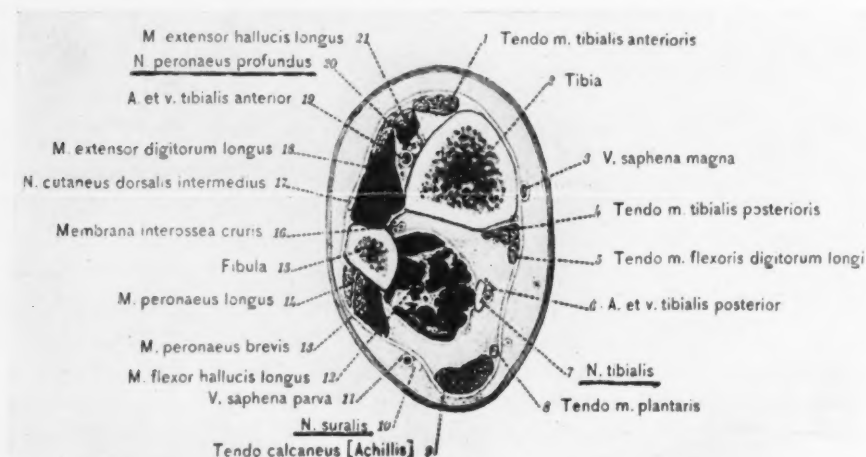


FIG. 1.—Cross-section of leg ($3\frac{1}{2}$ inches above internal malleolus) showing the position and relation of nerves in the lower extremity. (From Eycleshymer and Schoemaker: A Cross Section Anatomy, D. Appleton & Co.)

foot. These are the posterior tibial, deep peroneal (anterior tibial), superficial peroneal (musculocutaneous), sural (external saphenous), and the internal saphenous.

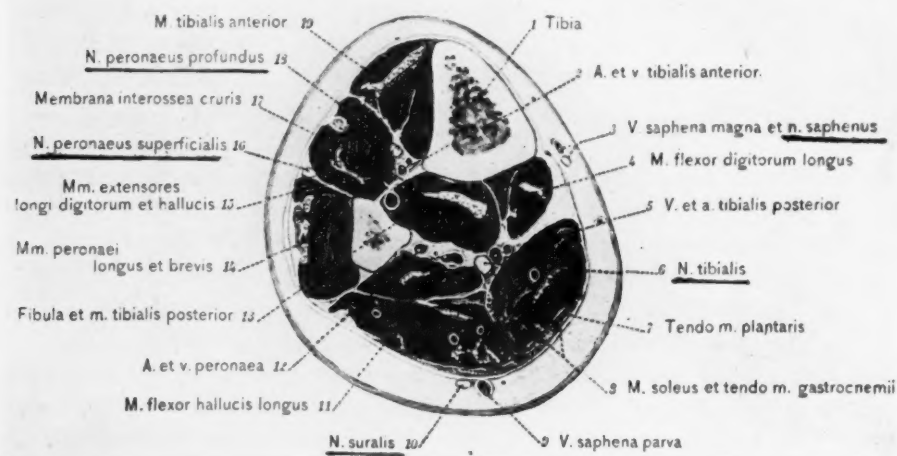


FIG. 2.—Cross-section of leg (5 inches above the internal malleolus) showing the position and relation of nerves in the lower extremity. (From Eycleshymer and Schoemaker: A Cross Section Anatomy, D. Appleton & Co.)

The posterior tibial nerve (Figs. 1, 2 and 3) is one of the terminal divisions of the sciatic nerve. It carries motor fibres to the muscles of the calf and the intrinsic muscles of the foot. Its sensory distribution is to the entire sole of the foot and the dorsum of the tips of the distal phalanges of all the toes. The course of the nerve is from the middle of the popliteal space downward and inward to the inside of the ankle. In

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the lower third of the leg it lies lateral to the posterior tibial blood vessels, becoming more posterior as the structures approach the ankle. The tendons of the flexor longus digitorum and posterior tibial muscles are anterior and the flexor hallucis longus is posterior to the neurovascular bundle. The nerve gives off a branch just above the ankle, the plantar interosseous (medial calcaneal) nerve, which perforates the internal annular ligament and supplies sensation to the heel and adjoining part of the sole of the foot and lower down divides into two branches (*a*) the internal (medial) and (*b*) the external (lateral) plantar nerves which are distributed to the rest of the sole and intrinsic foot muscles.

The deep peroneal (anterior tibial) nerve (Figs. 1, 2, 4 and 6) is a continuation of the common peroneal (external popliteal) nerve. It is a mixed nerve carrying motor fibres for the anterior leg muscles and intrinsic muscles of the foot. It supplies sensation to the tarsal bones and the joints of the foot. Its distribution in the skin is to the contiguous sides of the great (first) and second toes, and a small area between the heads of the first and second metatarsals. The nerve descends lateral to the tibia



FIG. 3.

FIG. 3.—Course of posterior tibial nerve showing calcaneal branch. (After Sappey.) (From Tinel, *Nerve Wounds*, William Wood and Company.)



FIG. 4.

FIG. 4.—Course of superficial and deep peroneal nerves showing the bifurcation of the former. (From Pollock and Davis, *Peripheral Nerve Injuries*, Paul B. Hoeber, Inc.)

and anterior to the interosseous membrane. In the lower third of the leg the nerve generally lies in front of the anterior tibial vessels. At its upper level the nerve lies between the anterior tibial and extensor digitorum longus muscles. Just above the ankle it lies between the extensor hallucis longus and the extensor digitorum longus.

The superficial peroneal (musculocutaneous) nerve (Figs. 1, 2, 4 and 6) also arises from the common peroneal. It gives off muscular branches in the upper third of the leg and is entirely sensory below this point. At the junction of the middle and lower thirds of the leg (about six inches above the ankle) it pierces the deep fascia and lower down divides into medial and lateral branches. It supplies sensation to the entire dorsum of the ankle and foot with the exception of the area between the base of the great and second toes (deep peroneal), lateral side of the foot and little toe (sural) and tips of toes (posterior tibial). The distribution of the terminal branches of this nerve varies and often the extreme lateral branch is replaced by the sural nerve.

The sural (external or short saphenous) nerve (Figs. 1, 2 and 5) is formed by the union of the lateral sural cutaneous nerve (branch of the common peroneal) either directly or through a connecting branch, the peroneal anastomotic, with the medial sural cutaneous nerve (branch of the sciatic). The junction of these two nerves may take place at any point between the popliteal space and the lower third of the leg. The nerve descends along the lateral border of the tendo achillis, passes posterior to the lateral malleolus and turning forward it continues along the lateral side of the foot and divides into two branches. It supplies sensation to the skin of the lower lateral

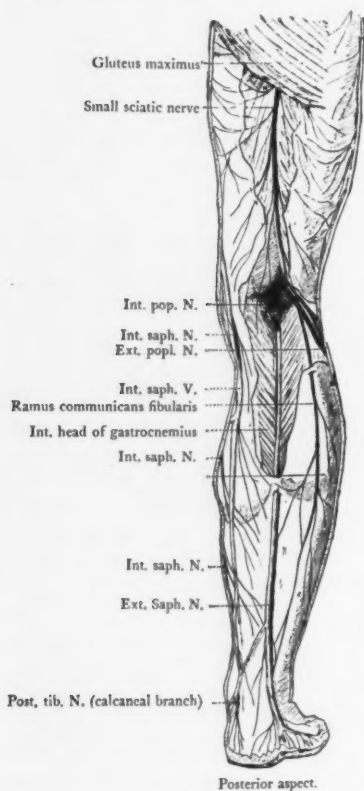


FIG. 5.

FIG. 5.—Course of the sural (external saphenous) nerve lying adjacent to the external saphenous vein. (After Hirschfeld.) (From Tinel, *Nerve Wounds*, William Wood and Company.)

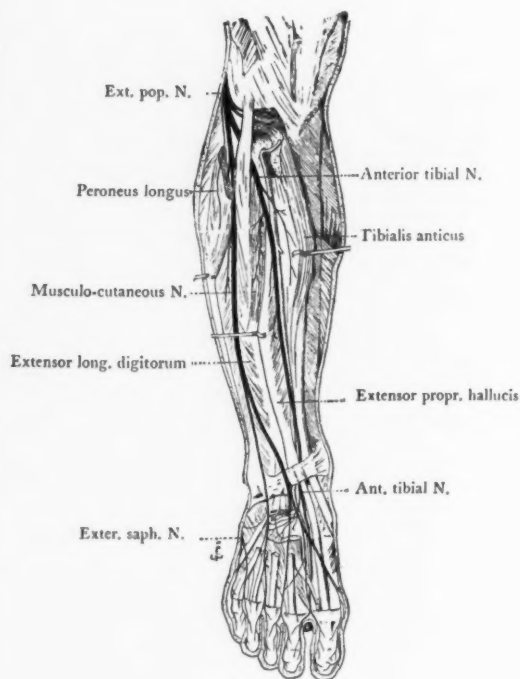


FIG. 6.

FIG. 6.—Course and distribution of the superficial and deep peroneal nerves. (After Hirschfeld.) (From Tinel, *Nerve Wounds*, William Wood and Company.)

part of the leg, lateral side of the heel and lateral side of the foot and dorsal and lateral surfaces of the fifth toe, often including the lateral side of the fourth toe.

The saphenous nerve (Figs. 1 and 2), one of the terminal branches of the femoral nerve, descends with the great saphenous vein along the inner border of the upper two-thirds of the tibia and then crosses the medial surface of the lower third of the tibia, passes in front of the internal malleolus to the ball of the great toe. This nerve supplies sensation to the integument of the medial side of the leg and foot.

Surgical Technic.—The posterior tibial nerve is exposed by a three-inch vertical incision one to four inches above the internal malleolus and about one inch behind the posterior border of the tibia or parallel to the inner margin of the tendo achillis. The deep fascia is opened and the neurovascular bundle is isolated by blunt separation of the fascial planes between the flexor digitorum longus and the gastrocnemius and

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soleus muscles. (Fig. 2.) The nerve lies about three-quarters to one inch beneath the skin surface and immediately beneath or lateral to the artery and vein. It is about three-eighths of an inch in diameter and can be mistaken for a tendon by an inexperienced operator. The operative incision may be made at a somewhat lower level, in which case the nerve lies directly under the deep fascia, posterior and slightly lateral to the artery and vein, with the tendon of the flexor hallucis longus lying posterior and the tendons of the flexor digitorum longus and posterior tibial lying anterior. If the nerve is sectioned at the malleolus or not more than one inch above it, the posterior half of the sole is not anesthetized inasmuch as the plantar interosseous (medial calcaneal) nerve comes off proximal to this point. (Fig. 3.) After exposure, the nerve is separated from the artery and vein with great care so as to damage the vascular structures as little as possible. One or two fine silk sutures are passed vertically through the nerve and the structure is then divided by a transverse incision. On tying the sutures the cut ends of the nerve are accurately approximated without rotation. A small blood-vessel is usually present in the posterior tibial nerve which must be ligated after section. After careful hemostasis, the skin wound is closed with a few interrupted silk sutures.

The deep peroneal (anterior tibial) nerve is exposed by a three-inch vertical incision about two to four inches above the ankle. The incision is made just lateral to the tendon of the extensor hallucis longus which can readily be palpated and should be placed about one-half inch lateral to the crest of the tibia. The deep fascia is incised and the neurovascular bundle exposed by blunt dissection between the extensor hallucis longus and the extensor digitorum longus muscles. (Fig. 1.) This bundle lies at a depth of about one and one-quarter inches in the average case. The nerve is the most anterior structure here and is about one-eighth inch in diameter. It is dealt with in exactly the same manner as has been described for the posterior tibial.

The superficial peroneal (musculocutaneous) nerve is exposed by a three-inch linear incision about five to six inches above the external malleolus, parallel to the border of the fibula and about one inch anterior to it. The nerve is usually found just beneath the deep fascia, though it is often just above it. It is ovoid in shape and about one-quarter inch in diameter and is not associated with any large vessels. It lies between the long and short peronei muscles on the lateral side and the extensor digitorum longus muscles on the medial side. (Fig. 2.)

The sural nerve is exposed by a vertical incision about five inches above the internal malleolus, just lateral to the mid-line. It lies above the deep fascia and close to the external saphenous vein and is about one-eighth inch in diameter. (Fig. 2.)

The saphenous nerve is exposed by a vertical incision five inches above the ankle in the middle of the medial surface of the leg. Its location is above the deep fascia usually posterior to the internal saphenous vein. It is about one-sixteenth to one-eighth inch in diameter. (Fig. 2.)

The operation may be done under local or spinal anesthesia. The former method has the advantage that it is possible to test the completeness of the procedure immediately by the area of anesthesia produced. When local anesthetics are used the exposed nerve must be anesthetized with novocaine before it is divided.

The most common site of ulceration in patients with thrombo-angiitis obliterans is the dorsal surface of the great toe. In order to produce anesthesia of this toe it is necessary to divide the posterior tibial, superficial and deep peroneal nerves. Anesthetization of the fourth toe usually necessitates the sectioning of the posterior tibial, superficial and deep peroneal and sural nerves. The deep peroneal nerve supplies deep sensation to the foot, *i.e.*, to the tarsal bones and joints, and unless this nerve is sectioned the

patient may continue to complain of pain, even though the skin in the ulcerated area is anæsthetic. Frequently an ulcer will enlarge so as to involve an unanæsthetized area and then another nerve must be divided. From a

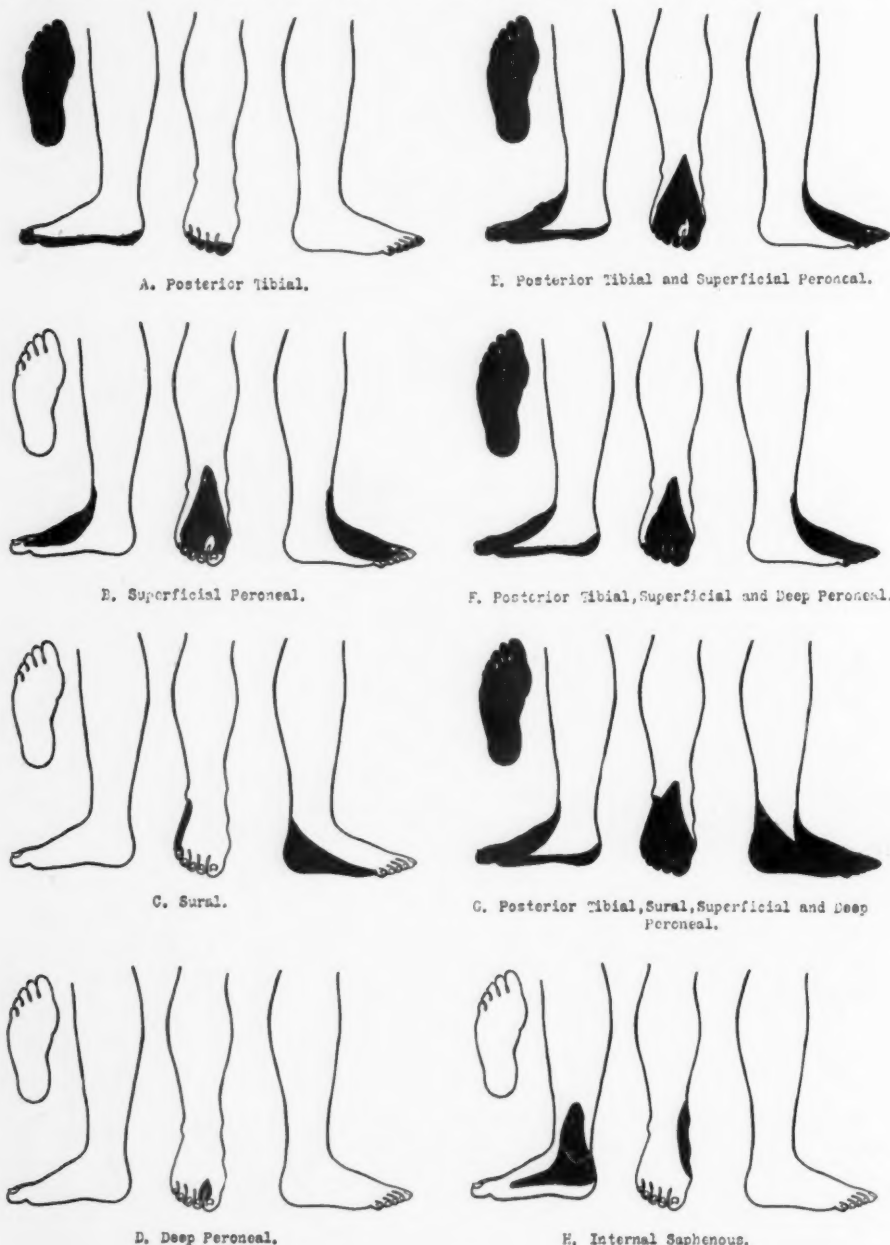


FIG. 7.—Areas of anæsthesia produced by section of one or more nerves.

study of Fig. 7 it is simple to decide what nerve or combination of nerves must be sectioned in order to produce anæsthesia of the desired area. We have noted that nerve determinations usually overlap in their sensory distri-

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bution and it is often necessary to produce a wide area of anaesthesia to desensitize marginal painful lesions.

It must be recognized that incisions to expose these nerves are made into relatively devitalized tissues. More than ordinary care to avoid trauma, and rigid asepsis to prevent even slight infection are essential if satisfactory healing of wounds is to take place. In our experience healing by primary union has been the rule, although in an occasional instance some difficulty has been experienced.

Since the nerve sections are carried out in the lower third of the leg, the innervation of all the leg muscles is left intact and no difficulty in walking results from the operation. Paralysis of the small intrinsic muscles of the foot is produced, but is of no importance, because these muscles are not employed in standing or walking. The loss of sensation requires that the patient use care to avoid injuring the foot. The wearing of shoes is usually sufficient to prevent such an accident. The anaesthesia induced is temporary, and a fairly satisfactory return of sensation may be anticipated in the course of time.

Occasionally section of one of the peripheral nerves is followed by incomplete anaesthesia in the area usually supplied by this nerve. This is due to some abnormality or unusual branching of the nerve. The course of the abnormal branch can be readily established by laying down a series of subcutaneous injections of novocaine. After each injection the area to be anaesthetized is tested. When the area suddenly loses its sensitivity, the aberrant nerve in question is exactly located by the last injection of novocaine. Exposure of the nerve by a small incision at this point and section as described results in satisfactory anaesthesia.

The method described above has been carried out in eighteen cases selected from patients under treatment in the Thrombo-Angiitis Obliterans Clinic in the Out-Patient Department of the Mount Sinai Hospital and from the authors' private practices. All of the patients operated upon had ulcerative or gangrenous lesions of the foot. All had been suffering severely for some time previous to the operation. These patients had been receiving the routine treatment of intravenous injections of hypertonic saline solution as well as surgical care of the local lesions. The value of nerve section as an additional measure in those patients suffering with severe pain is strikingly illustrated in the following cases:

CASE I.—N. R., male, aged forty-one. Russian-Hebrew, barber by trade, had a typical history of thrombo-angiitis obliterans with intermittent claudication for past fourteen years. Within this period he had lost one toe. He smoked twelve cigarettes daily. In August, 1931, he had developed an ulcer one and one-half to one-half inch on the stump of the left second toe and adjoining surface of big toe. He complained of severe pain and was unable to sleep. No pulse could be felt in the foot and the oscillometer reading at the ankle was one and one-quarter. Under local anaesthesia the posterior tibial, superficial and deep peroneal nerves were sectioned. Relief of pain was immediate and the patient slept thereafter without medication. The operative incisions healed by primary union. The ulcers were dressed daily and Dakinized. By

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September, 1931, the ulcers were entirely healed. In April, 1932, he injured the bottom of the left big toe by means of a nail and a round ulcer about one-quarter inch in diameter appeared. This healed slowly on strapping with adhesive. Examination in October, 1932, revealed that about 90 per cent. of the sensation had returned in his foot.

CASE II.—B. L., male, aged thirty-seven, Russian-Hebrew, tobacconist by occupation. He had suffered with thrombo-angiitis obliterans and intermittent claudication for three years. In 1928 he had lost one toe. His tobacco consumption was forty cigarettes daily. In November, 1931, he presented himself with an ulcer one-half to three-quarters of an inch in diameter on the dorsum of the left second toe directly over the phalangeal joint. No pulse could be felt in the left foot. The oscillometer reading at the ankle was 0.4. Pain was the cardinal symptom. An anæsthetic ointment had been used previously and the ulcer had become larger. Under spinal anæsthesia the posterior tibial, superficial and deep peroneal nerves were sectioned and the left second toe amputated. Complete relief of pain was accomplished immediately. The operative incisions healed by primary union. Healing of the ulcer was delayed by the presence of a small sequestrum, but at the end of five months complete healing had occurred. In September, 1932, sensation had returned to the entire foot except the tip of the big toe. There has been no recurrence of ulceration.

CASE III.—H. D., male, aged thirty-nine, Polish-Hebrew, writer by occupation. He had a typical history of thrombo-angiitis obliterans for the past eight years. In 1923 he had lost his left leg. He smoked twenty-five cigarettes daily. In February, 1932, ulcers were present on the right fourth and fifth toes, and the third toe was gangrenous. He complained of severe pain and was taking large doses of morphine without relief. The oscillometer reading at the ankle was 0.5. No pulse could be felt in the foot. Under spinal anæsthesia the posterior tibial, superficial and deep peroneals and sural nerves were sectioned. Complete relief of pain was obtained and the patient was at once made comfortable. Later the fourth and fifth toes became gangrenous and were removed with the third toe. The operative incisions healed by primary union. He was dressed daily and Dakinized and by May, 1932, the ulcers had entirely healed and have not recurred. Sensation is returning.

CASE IV.—L. B., male, aged thirty-nine, Austrian-Hebrew, clerk by occupation. He gave a typical history of thrombo-angiitis obliterans for two years. In February, 1932, an ulcer developed on the right second and third toes. He had severe pain and had been unable to sleep for the past three weeks. He smoked twenty cigarettes daily. On April 4, 1932, an examination revealed deep ulcers one-half to one inch on the dorsum of the right second and third toes. No pulse could be felt in the right foot. The oscillometer reading at the ankle was 1.0. Under local anæsthesia the posterior tibial, superficial and deep peroneal nerves were sectioned. Complete anæsthesia and relief of pain were obtained and the patient was able to sleep without medication. A few days later the second and third toes became gangrenous and were removed. Subsequently the fourth toe became gangrenous and patient complained of pain in the fifth toe. The sural nerve was therefore divided under local anæsthesia and complete relief of pain followed. Later the fourth toe was removed. The operative incisions healed by primary union. Dakinization and daily dressings with a bland ointment were instituted. By July, 1932, the foot had entirely healed. Sensation in the foot has begun to return.

CASE V.—S. M., male, aged forty-eight, Russian-Hebrew, tailor by trade. He gave a history of intermittent claudication for six months with migrating phlebitis a few years previous. He smoked twenty cigarettes daily. In October, 1931, a small ulcer appeared on the left big toe and by May, 1932, it had progressed so that the entire toe was gangrenous. He had severe pain and had not slept for many weeks, even with narcotics. No pulse could be felt in the left foot. The oscillometer reading at the ankle was zero (0). Under spinal anæsthesia the posterior tibial, superficial

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and deep peroneal nerves were sectioned. Complete relief of pain was obtained. The operative incisions healed by primary union. Later the gangrenous left big toe was removed. (Fig. 8.) An infection at the base of the amputated toe developed and was incised and drained. With Dakinization and daily dressings the wound had entirely healed by October, 1932. The patient is now walking and is free from pain. Sensation has already returned to a considerable degree.

CASE VI.—A. G., male, aged forty-two, Russian-Hebrew, clothes cutter by occupation. He had a typical case of thrombo-angiitis obliterans for eight years with intermittent claudication in both legs after walking one-half block. He smoked fifteen cigarettes daily. In March, 1932, the right big toe became gangrenous. Both popliteal arteries were closed and there was no pulse in either foot. The oscillometer reading at both ankles was zero (0). He had severe pain. We recognized this as a particularly unfavorable case because of the very advanced impairment of circulation, but decided to try nerve section combined with femoral vein ligation as a last resort before proceeding to amputation. Under local anaesthesia the posterior tibial, superficial and deep peroneal nerves were sectioned. Complete anaesthesia and relief of pain was obtained. The patient continued to smoke. The gangrene progressed and the operative incisions did not heal, so that a high amputation was necessary.

CASE VII.—S. L., male, aged twenty-seven, Russian-Hebrew, glazier by trade. He was a typical case of thrombo-angiitis obliterans with an eight months' history of intermittent claudication after walking one and one-half blocks. He smoked fifteen cigarettes daily. In June, 1932, an ulcer three-quarters of an inch in diameter was present on the plantar surface of the left fourth toe, extending onto the sole. There was a small anterior tibial pulse in the left foot. The oscillometer reading at the ankle was 0.5. He complained of severe pain. Under local anaesthesia the posterior tibial and sural nerves were sectioned. Relief of pain was accomplished. Later the ulcer extended into the region supplied by the superficial peroneal nerve and this also was sectioned. Pain was then entirely relieved. The operative incisions healed by primary union. About a week after nerve section the patient complained of transitory shooting pains in the entire foot, which disappeared after ten days. With daily dressings and Dakinization the ulcer healed slowly.

CASE VIII.—J. B., male, aged thirty-two, Russian-Hebrew, painter by trade. He was a typical case of thrombo-angiitis obliterans with intermittent claudication for the past five years. He smoked eighteen cigarettes daily. In January, 1932, an infection commenced under the left big toe and spread rapidly so as to involve the entire digit. He complained of severe pain. There was no pulse in either foot and both popliteals were closed. The oscillometer reading at both ankles was zero (0). Under local anaesthesia the posterior tibial, superficial and deep peroneal nerves were sectioned. Complete relief of pain was obtained. The operative incisions healed by primary union. Gangrene progressed rapidly and involved almost the entire foot, but pain did not recur. The patient showed evidence of considerable toxic absorption, and since a useful foot could no longer be saved, an amputation five inches below the knee was done. The stump healed by primary union in about three weeks.

CASE IX.—F. F., male, aged forty-three, Puerto Rican, wireman by occupation. He had complained of intermittent claudication and cold feet for a few years. He smoked twenty cigarettes daily. No pulse could be felt in either foot and the oscillometer reading at the ankles was very faint. In July, 1932, an ulcer appeared on the right big toe and rapidly became larger so that the entire toe was soon gangrenous. There was also an ulcer at the base of the right fifth toe. The pain was severe. Under local anaesthesia the posterior tibial, superficial and deep peroneals and sural nerves were sectioned. This produced anaesthesia of the entire foot except the fourth toe and an area one inch in diameter at the base of this toe. The fourth toe became entirely gangrenous and local pain recurred. The anterior branch of the sural nerve had



FIG. 8.

FIG. 8.—(Case V.) Photograph showing foot entirely healed after removal of gangrenous big toe. Area of anesthesia indicated. Note healed scars of nerve sections in lower leg. (November, 1932.)

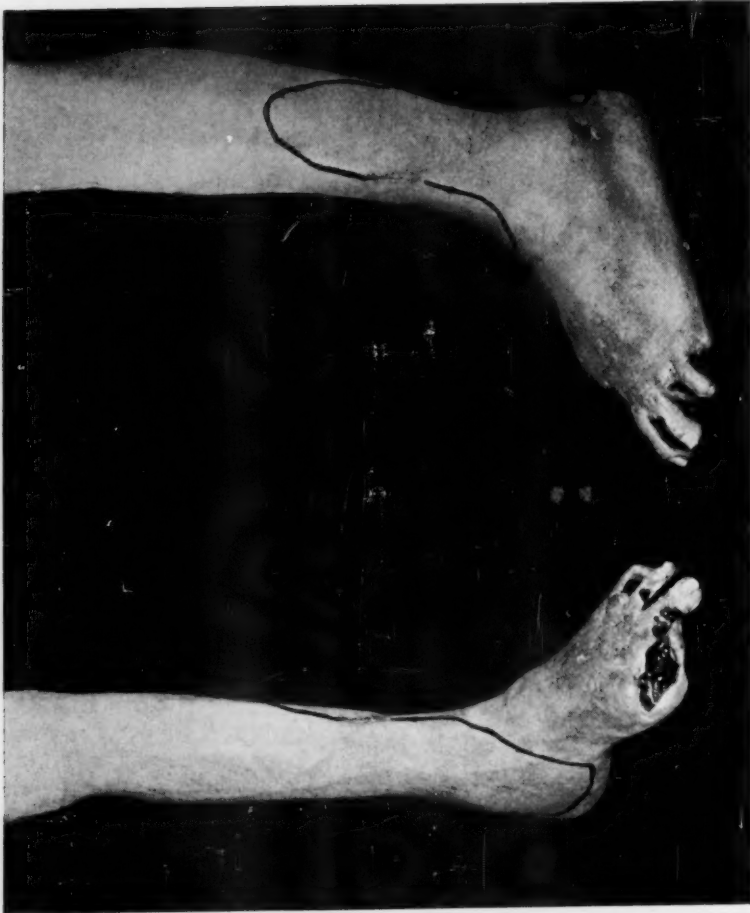


FIG. 9a.

FIG. 9a.—(Case IX.) Photograph showing ulcers on foot after removal of gangrenous big and fourth toes. Area of anesthesia indicated. Note healed operative incisions in lower leg. Four months after operation. (November, 1932.)

FIG. 9b.—(Case IX.) Photograph showing ulcers on foot after removal of gangrenous big and fourth toes. Area of anesthesia indicated. Note healed operative incisions in lower leg. Four months after operation. (November, 1932.)

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escaped section at the previous operation. Its course was located by novocaine injections as lying directly below the external malleolus and it was then divided. Complete relief of pain was promptly obtained. The operative incisions healed by primary union. The foot was Dakinized and bland ointment dressings applied. The right big toe and fourth toe were removed (Fig. 9) and the foot is entirely healed at present.

CASE X.—E. K., male, aged thirty-four, Russian-Hebrew, truckman by occupation, had a typical case of thrombo-angiitis obliterans for five years with intermittent claudication. He was able to walk only one-half block. He smoked twenty cigarettes daily. No pulse could be felt in either foot. The oscillometer reading at both ankles was very faint. In August, 1931, an ulcer developed on the lateral side of the right second toe and progressed to involve the right big toe. Both toes became gangrenous and the patient suffered severely on account of pain. Under spinal anaesthesia the posterior tibial, superficial and deep peroneal nerves were sectioned. Complete relief of pain was obtained immediately. The operative incisions healed by primary union. The gangrene progressed rapidly and the patient showed signs of a spreading infection with temperature of 104°. An immediate thigh amputation was therefore necessary. Following this, the patient made an uneventful recovery.

CASE XI.—B. F., male, aged forty-two, Russian-Hebrew, clothes cutter by occupation, gave a typical history of thrombo-angiitis obliterans. He smoked fifteen cigarettes daily. In January, 1932, he had a painful ulcer, one inch by one-half inch, over the left internal malleolus. No pulse could be felt in either foot and the oscillometer reading at the ankles was 0.3. In January, 1932, under local anaesthesia, the internal saphenous nerve was sectioned and anaesthesia produced with complete relief of pain. The ulcer and operative incision healed slowly. By December, 1932, sensation had entirely returned.

CASE XII.—C. F., male, aged forty-eight, Scotch-American, clerk by occupation. He had a history of intermittent claudication in the left leg for eight years and in the right leg for three months. He smoked heavily. Seven years ago he had lost three toes of the left foot. (Fig. 10.) He also had recurrent ulcers of both hands. Examination revealed gangrene of the right first, second, third and fourth toes extending over onto the dorsal and plantar surfaces of the foot. The oscillometer reading at the ankles was very faint. He had severe pain. In July, 1932, under spinal anaesthesia the posterior tibial, superficial and deep peroneals and sural nerves were sectioned. Complete relief of pain was accomplished. The operative incisions healed by primary union. The gangrenous toes and protruding bones were subsequently removed. The foot is almost entirely healed.

CASE XIII.—D. N., male, aged forty-five, Russian-Hebrew, window cleaner by occupation. He gave a history of intermittent claudication in the right leg for one year and an ulcer on the right big toe for five months. He smoked fifty cigarettes daily. He had considerable pain. Examination revealed an ulcer one by two centimetres on the right big toe extending under the nail. The femoral pulse was open, but the popliteal was closed. There was no pulsation at the ankle. The oscillometer reading at the ankle was very faint. In May, 1932, under local anaesthesia, the posterior tibial, superficial and deep peroneal nerves were sectioned. Complete relief of pain was obtained. The operative incisions healed by primary union. The distal half of the big toe was later amputated. Subsequently an infection developed on the sole and dorsum of the foot and was drained. There was progression of the infection involving the ankle-joint, so an amputation five inches below the knee was required. The stump healed rapidly.

CASE XIV.—A. L., male, aged forty-six, Russian-Hebrew, gave a typical history of thrombo-angiitis obliterans. For one month he had an ulcer on the right fourth toe with severe pain. He smoked ten cigars daily. Examination revealed an ulcer on the posterior and lateral surfaces of the right fourth toe. There was no pulse in the foot and the oscillometer reading at the ankle was zero (0). In September, 1932, under local

anæsthesia, the posterior tibial, superficial peroneal and sural nerves were sectioned. This produced complete anæsthesia of the fourth toe, but some pain persisted. This was subsequently relieved by section of the deep peroneal nerve. The operative incisions healed by primary union. The fourth toe became completely gangrenous and was removed. The ulcer is healing rapidly.

CASE XV.—M. F., male, aged twenty-five, Russian-Hebrew, carpenter by trade. He gave a typical history of thrombo-angiitis obliterans for two years with marked involvement of the right upper extremity. For the past four months he had an ulcer on the right big toe one and one-half inches in diameter involving the interphalangeal joint. He complained of severe pain. He smoked fifteen cigarettes daily. There was no pulse in the right foot. The oscillometer reading at the ankle was 2.5. In November, 1931, under local anæsthesia, the posterior tibial, superficial and deep peroneal nerves were sectioned. Complete relief of pain was obtained. The operative incisions healed by primary union. The distal portion of the big toe was amputated and the ulcer healed in a few months.

CASE XVI.—I. F., male, aged forty-seven, American-Hebrew, newsdealer by occupation. He gave a typical history of thrombo-angiitis obliterans with the loss of the left leg three years previously. He smoked thirty cigarettes daily. The present condition commenced a few months ago with ulcers on the right second, third, fourth and fifth toes. This progressed to gangrene and spontaneous amputation. He then presented a large ulcer at the base of the toes and on the dorsum and sole of the foot. He had severe pain. The femoral pulse was the only one in the right lower extremity. The oscillometer reading at the ankle was very faint. In June, 1931, under local anæsthesia, the posterior tibial, superficial and deep peroneal nerves were sectioned. Almost complete relief of pain was obtained. (Fig. 11.) This was due to the fact that the sural nerve was not divided, leaving some sensation in the fifth toe. The operative incisions healed in four months and sensation has returned to the entire foot as far as the big toe. There has been no recurrence of pain or ulceration.

CASE XVII.—S. R., male, aged sixty years, Russian-Hebrew, theatre manager by occupation, was a border-line case of thrombo-angiitis obliterans with a history of intermittent claudication for six years. He smoked twenty cigarettes daily. For the past two months he had severe pain and impending gangrene of the right foot. There was no pulse at the right ankle and the oscillometer reading at the ankle was very faint. In February, 1932, under local anæsthesia, the posterior tibial, superficial and deep peroneal nerves were sectioned. There was complete relief of pain. The first and second toes became gangrenous, demarcated and amputated spontaneously. The operative incisions healed by primary union. The ulcers at the base of the toes are healing rapidly. There has been a partial return of sensation.

CASE XVIII.—F. A., male, aged twenty-two, Italian, clothes cutter by trade. He was a typical case of thrombo-angiitis obliterans with a history of intermittent claudication for two years. He smoked twenty cigarettes daily. For about six months he had had an ulcer on the left big toe with severe pain. (Fig. 12.) There was no pulse in the foot and the oscillometer reading at the ankle was faint. In December, 1932, under spinal anæsthesia, the posterior tibial, superficial and deep peroneal nerves were sectioned. There was complete relief of pain. The operative incisions healed by primary union. The ulcer is healing rapidly.

The relief of pain as the result of nerve section presented by every one of the cases detailed is most notable and encouraging. In a few some vague discomfort remained, and some patients complained of occasional sharp, shooting pains for a time, probably due to nerve-end irritation. All of the operative wounds healed by primary union, except in one case of very advanced impairment of circulation. (Case VI.) In all the operated cases



FIG. 10.

FIG. 10.—(Case XII.) Photograph showing ulcers on foot after amputation of gangrenous toes. Area of anesthesia indicated. Note healed operative scars of

FIG. 11.—(Case XVI.) Photograph showing nerve sections in lower leg. Four months after operation. (November, 1932.)

FIG. 12.—(Case XVIII.) Photograph showing healed foot with small residual area of anesthesia indicated on big toe. Sixteen months after nerve section. (November, 1932.)

FIG. 11.

FIG. 11.—(Case XVI.) Photograph showing nerve sections in lower leg. Four months after operation. (November, 1932.)

FIG. 12.—(Case XVIII.) Photograph showing healed foot with small residual area of anesthesia indicated on big toe. Sixteen months after nerve section. (November, 1932.)

FIG. 12.—(Case XVIII.) Photograph showing healed ulcer on big toe. Area of anesthesia indicated. Note recently healed operative incisions in lower leg. (December, 1932.)

FIG. 12.

FIG. 12.—(Case XVIII.) Photograph showing healed ulcer on big toe. Area of anesthesia indicated. Note recently healed operative incisions in lower leg. (December, 1932.)

FIG. 12.—(Case XVIII.) Photograph showing healed ulcer on big toe. Area of anesthesia indicated. Note recently healed operative incisions in lower leg. (December, 1932.)

pulsation at the ankle was absent, and readings with the Pachon oscillometer were very much diminished. In seven of the eight patients in whom the popliteal artery was also closed, healing of the operative wounds was satisfactory.

Such results warrant the conclusion that advanced impairment of circulation need not deter one from proceeding with nerve section, inasmuch as healing of the operative wounds is the rule. Trophic ulceration did not occur in any of our cases, which have been observed for two years following the operation. One small ulcer, due to trauma from a nail in the shoe, occurred in Case I. This healed under the usual method of treatment.

It is difficult to estimate the rate of healing in ulcers, but it is our impression that following nerve section, the rate of healing was accelerated. Due to the loss of sensitivity in the ulcerated areas, more efficient treatment of these wounds was possible. In contrast to the great distress that the patient suffered from dressings before operation, the treatment after nerve section was entirely painless. The wounds could be adequately cleansed with ether and immersed in Dakin's solution. Necrotic tissue or bone fragments could be removed without pain, and gangrenous toes, when well demarcated, could be amputated. When the wound surface became healthy, strapping with adhesive strips was frequently utilized. It is not possible to say to what extent this improved care of the wounds, rather than the nerve section itself, was responsible for the apparent acceleration in healing.

Major amputations were done in four of our cases; in two because of spreading infection and in the other two on account of extensive gangrene. In all of these four cases, nerve section had given satisfactory results as far as the relief of pain was concerned. The significance of this relatively high percentage of amputations must be considered in the light of the fact that almost all of these patients represented very advanced cases of thrombo-angiitis obliterans.

Evidence of nerve regeneration was present in all cases in which sufficient time had elapsed after operation. Usually a period of about a year is necessary for complete return of sensation, the time varying with the level at which the nerve section was done. Most of the patients in the group presented have gone to complete healing of the affected foot and are walking without any difficulty. In none of them has there been any return of pain or recurrence of ulceration.

The advantage of nerve section in patients with thrombo-angiitis obliterans who have painful ulcers of the foot is apparent in the cases presented above. We wish to make it clear that nerve section is in no way a specific treatment for thrombo-angiitis obliterans, and has no place except for the relief of pain of the type due to ulceration or gangrene. It will not relieve intermittent claudication. Since vasoconstrictor fibres are carried in the peripheral nerves, section of these is followed by vasodilatation, as shown by the work of Morton and Scott.⁵ Thus the local advantages of a lumbar ganglionectomy are obtained without subjecting the patient to a formidable

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operation, and at the same time relief of pain is far more complete due to section of the sensory fibres. It might be added that peripheral nerve section is so simple and safe, that it can be undertaken by any surgeon, while a ganglionectomy is an operation which requires special skill.

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PERIPHERAL VASOCONSTRICTION BY TOBACCO AND ITS RELATION TO THROMBO-ANGIITIS OBLITERANS

BY WALTER G. MADDOCK, M.D., AND FREDERICK A. COLLIER, M.D.
OF ANN ARBOR, MICH.

FROM THE DEPARTMENT OF SURGERY, UNIVERSITY OF MICHIGAN

FROM clinical observations, very definite opinions have been expressed concerning the relationship of tobacco to thrombo-angiitis obliterans:

Erb,¹ in 1904, concluded that tobacco smoking was a definite contributing factor to the production of peripheral vascular deficiencies. Buerger² assigns tobacco smoking as a predisposing cause of thrombo-angiitis obliterans and states that it is possible that the use of tobacco may render the vessels more susceptible to special agents, toxic or infectious, but that tobacco is the only cause or the exciting cause is exceedingly doubtful. Brown, Allen and Mahorner³ agree with Buerger. Willy Meyer⁴ presents tobacco-smoke poisoning as the one etiological factor responsible for the characteristic syndrome of thrombo-angiitis obliterans. Silbert,⁵ in reviewing 289 cases of this disease, is convinced that smoking is the most important contributing factor in producing the disease and that cessation of smoking is an essential therapeutic measure. He stated that 50 per cent. of the patients requiring amputation continued to smoke in spite of repeated warnings and that recurrence of symptoms after the individual had been restored to good condition was almost invariably traceable to a resumption of smoking. In only two of Silbert's cases had a progression of the disease taken place when the patient was not using tobacco. Samuels⁶ insists that the first point in the treatment of thrombo-angiitis obliterans is the absolute prohibition of the use of tobacco.

The study by Barker⁷ of the tobacco usage at the onset of the symptoms, not that used after severe pain or gangrene, in 350 cases of thrombo-angiitis obliterans, shows conclusively that a greater percentage (87 per cent.) of the individuals with that disease use tobacco than do other groups; that they smoke cigarettes much more (91.5 per cent.) than other forms of tobacco; that as a group they consume more tobacco than other individuals and finally, that the severity of their disease is greater in the excessive users than that in the very few non-users and mild users of tobacco.

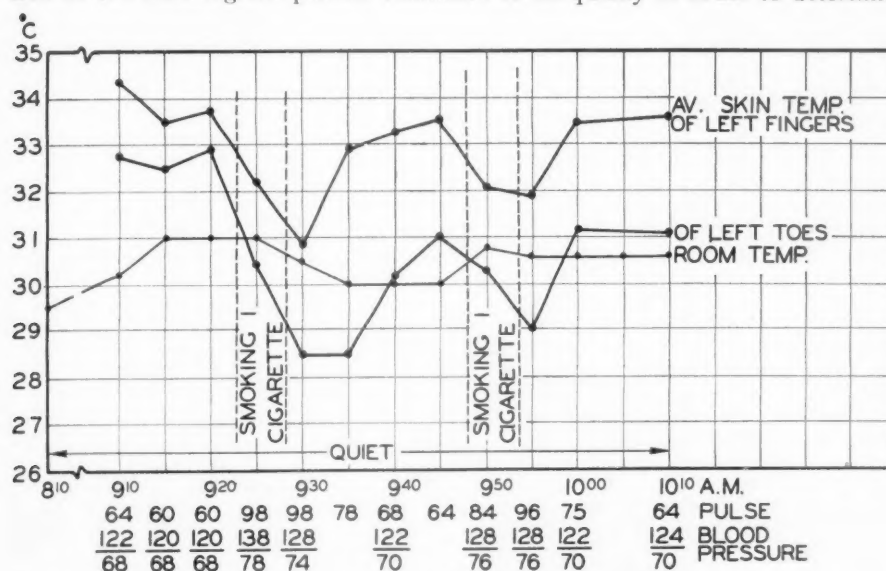
A considerable amount of experimental work has been done with tobacco and its derivatives. In the literature we have found only three investigations^{8,9,10} demonstrating the peripheral vasoconstrictor effect of tobacco smoking in man. We have seen no reference to these articles in discussions of the possible relationship of tobacco smoking to thrombo-angiitis obliterans. Recently, in a preliminary report,¹¹ we presented definite evidence of the peripheral vasoconstrictor action of tobacco smoking in man by means of skin-temperature changes. We wish here to report this work in detail.

Normal subjects.—The investigation was carried on in a small room in which the temperature could be controlled at a fairly constant level, the range being from 25.0° to 28.0° C.* A small electric fan running at low

* In order to show an increase in peripheral vasoconstriction it was not desirable to have the normal peripheral vasoconstriction at its maximum at the onset of the experiment. Accordingly, fairly warm room temperatures were used, under which condition peripheral vasoconstriction is at a low degree or may be entirely lacking.

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speed provided a circulation of air. No talking was allowed and every effort was made to eliminate psychic factors. The subject, lying quietly on a bed and wearing shorts in the case of the men and shorts and a breast covering in the case of the women, was exposed to the environmental conditions for one hour.* At five-minute intervals blood-pressure and pulse readings were then made on the right arm and skin-temperature measurements were taken with a "Tycos Dermatherm" on the palmar tips of the left fingers and the plantar tips of the left toes.† On some subjects the skin temperature just above the umbilicus and of the right toes was recorded. After a fairly constant skin-temperature level had been reached the subject was given his customary form of tobacco to smoke at his usual rate. Following completion of the smoking the patient continued to lie quietly in order to determine



C.F.-AGE 25 - SMOKES 20 CIGARETTES PER DAY - INHALES

FIG. 1.—The effect of cigarette smoking on blood-pressure, pulse rate and peripheral skin temperature.

whether the cardiovascular changes that resulted during the smoking period would return to their previous levels. The experiment was carried out with twenty subjects between twenty and thirty years of age, the majority of whom were medical students. Both light and heavy smokers were included in the group.

Under the conditions of the study the data obtained from subject C. F. and shown in Fig. 1 demonstrated that with smoking there occurred an increase in blood-pressure and pulse rate and a decrease in the skin temperature of the left fingers and toes. On cessation of smoking the first cigarette,

*This initial period was selected in order to allow for an adaptation of the skin temperature to the environmental temperature.

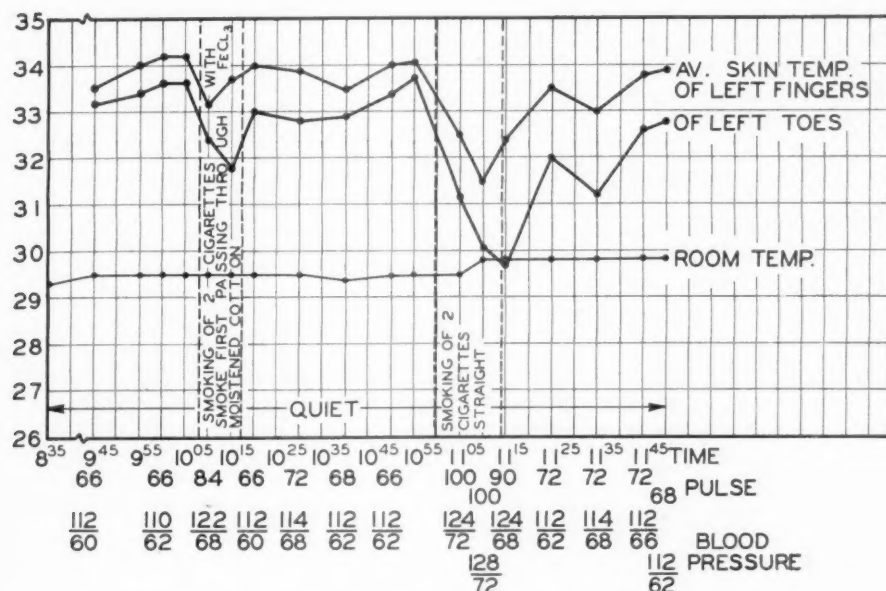
† These measurements were taken routinely on the one side only because it has been repeatedly shown^{12, 13} that normally the skin temperature of symmetrical body points is approximately the same.

TABLE I
Blood-Pressure, Pulse Rate and Skin-Temperature Changes with Tobacco

Subject.....	1 H.S.	2 C.F.	3 C.H.	4 S.B.	5 C.F.	6 H.J.	7 R.H.	8 C.H.	9 M.F.	10 H.B.	11 M.B.
Age.....	18	26	23	24	25	25	28	23	29	30	23
Sex.....	F.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.
Average smoking per day	20	20	12	20	18	15	20	12	35		15
Cigarettes.....										6	
Pipefuls.....											
Inhales smoke.....	+	+	+	+	+	+	+	+	+		
Smoked during test—cigarettes or pipefuls...	1	1	2	2	2	3	3	3	2	2	4
Time smoking—minutes.....	7	5	20	20	14	25	15	25	12	44	25
On smoking											
Increase in systolic B.P. in mm. of Hg....	20	18	8	20	16	18	10	10	18	8	10
Increase in diastolic B.P. in mm. of Hg....	14	10	25	10	6	16	0	20	10	10	4
Increase in pulse rate per minute.....	8	38	20	20	34	18	18	16	26	24	12
Decrease in av. skin temp. left fingers in °C.	4.5	2.8	3.0	1.5	2.5	2.2	3.5	6.0	4.5	3.0	0.7
Decrease in av. skin temp. left toes in °C..	2.5	4.5	1.0	3.0	4.0	4.5	0.5	2.0	4.3	2.5	1.6
Time required in minutes to return to level previous to smoking											
Systolic B.P.....	20	12	14	15	10	15	15	12	10	20	4
Diastolic B.P.....	20	12	20	6	10	15	15	12	10	30	2
Pulse rate.....	20	15	20	5	15	5	15	12	10	30	4
Skin temperature, fingers.....	5	15	70	20	45	35	20	60	10	40	10
Number of degrees C. of the temperature of the toes below their pre-smoking level at the time the temperature of the fingers had returned to their original level.....	1.5	1.8	0.0	1.5	1.0	2.0	0.0	1.0	3.5	2.5	0.5

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the blood-pressure and pulse rates returned to their previous level in approximately twelve minutes; the skin temperatures of the fingers increased to their previous level in seventeen minutes, while at that time the toes were still 2.0° C. below their original temperature. The same response occurred on smoking a second cigarette. The nineteen other subjects in this group on smoking showed the same changes to a greater or less degree as the example presented. The data from eleven of them are given in Table I. Occasionally a subject noted mild vertigo and nausea on smoking. This was stated to be no greater than often experienced in their usual smoking habits. There were no significant changes in mouth temperature and skin temperature about the waist during an experiment. The magnitude of the changes



C.F. AGE 25 SMOKES 20 CIGARETTES PER DAY INHALES

FIG. 2.—A lessened cardiovascular response as a result of the smoke first passing through a filter.

in blood-pressure, pulse rate and peripheral skin temperature was greater with rapid smoking than with slow smoking and again with "inhaling" the smoke than with merely "puffing." (Subject 11, Table I.)

Subject 9 of Table I, an Austrian Jew, smoked thirty-five to forty cigarettes per day. In spite of this habitual excessive use of tobacco there was a marked cardiovascular response to the smoking of two cigarettes. In subject 10 of Table I the usual changes recorded on cigarette smoking were noted from pipe smoking.

The possibility was raised that some other factor than tobacco smoke was responsible for the result obtained. Accordingly, a series of control experiments was made. These consisted of changing the original conditions of the smoking experiment as follows: First, the substitution of cubebs for cigarettes, and second, by having the subject go through the motions of

smoking with a small paper tube or an empty pipe. With these substitutions there were negligible changes in blood-pressure, pulse rate and peripheral skin temperature. In the third group of controls the smoke was first passed through two water bottles or through a layer of cotton moistened with FeCl_3 ,⁹ thereby removing some of its components. A decreased cardiovascular response resulted, an example being shown in Fig. 2.

The data from these control experiments substantiated our opinion that the increase in blood-pressure and pulse rate and the decrease in peripheral skin temperature found on smoking were due to active products absorbed from the tobacco smoke. This conclusion is in entire accord with the work of Simici and Marcu.⁹

The decrease in the peripheral skin temperature of our young adult group on smoking was of particular interest to us. This effect must be due to increased peripheral vasoconstriction. From a contemplation of this fact, several questions arose. We did not attempt to enumerate nor to answer all of them in this study. Of special interest appeared:

- (1) Through what mechanism does tobacco smoking produce peripheral vasoconstriction in man?
- (2) What components or component of the tobacco smoke is responsible for this action?

In 1908, Lee¹⁴ presented the composition of tobacco smoke obtained by an aspirator from the slow combustion of 100 grams of tobacco as follows:

Nicotine, 1.165 grams. This represented 50 per cent. of the total nicotine present before combustion. Pyridine bases, 0.146 gram, chiefly pyridine and collodine, the former being produced during the destruction of some of the nicotine, the latter from the combustion of the fibres in the tobacco. Hydrocyanic acid, 0.08 gram; ammonia, 0.36 gram; carbon monoxide, 410 cubic centimetres.

Many ingenious animal experiments support the view that the site of action of a tobacco infusion¹⁵ and of nicotine lies in the vasomotor nervous system. Langley and Dickinson¹⁶ proved that nicotine stimulates sympathetic ganglion cells. Hoskins and Ransom¹⁷ consider the pressor effect of nicotine due about one-half to a stimulation of the vasoconstrictor centre proper in the medulla and one-half to a stimulation of the sympathetic ganglion cells.

A few variations in our original smoking procedure presented data in man in accord with these conclusions. The decrease in the skin temperature of the toes shown on smoking was approximately the same for both feet. On two normal subjects a block of the left posterior tibial nerve with 2 per cent. procaine was done at the tip of the medial malleolus. This procedure interrupted the nerve supply to the plantar surface of the left toes. The usual smoking experiment was then started and both subjects showed the same result. On smoking a decrease occurred in the skin temperature of the right toes but did not occur in the left toes where the nerve was blocked.

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It was evident, then, that the peripheral vasoconstriction produced by tobacco smoking in these two normal subjects was brought about through the nerve mechanism and was not a direct effect on the musculature of the vessel walls.

This phase of our investigation was furthered by the opportunity to do the smoking experiment on an individual who had had a cervicodorsal ramusectomy and ganglionectomy and a lumbar ganglionectomy for Raynaud's disease. The sympathetic nervous system control to the extremities of this individual was abolished by this procedure. On smoking, the usual blood-pressure and pulse increase were found but no change occurred in the peripheral skin temperature. With this fact in view, we proceeded one step further from the conclusion reached as a result of the nerve-block experiment and considered that the peripheral vasoconstriction produced by tobacco smoking was brought about through the sympathetic nervous system.

Nicotine.—From animal experimentation Lee¹⁴ concludes that nicotine is the most important poison in tobacco. Cushny¹⁸ considers it to be the only constituent of tobacco possessing any toxicological interest. Sollmann¹⁹ states that the effects of tobacco are due practically solely to its nicotine content and that nicotine is absorbed extremely rapidly from the mucous membranes and especially from the lungs. We were interested then in determining whether nicotine administered by other channels would produce the same effect on blood-pressure, pulse rate and peripheral skin temperature as that shown by our young adults when smoking cigarettes.

A recent study²⁰ reported the average nicotine content of four popular brands of cigarettes to be 2.2 per cent. Since there is approximately one gram of tobacco in each of these cigarettes, there is an average of twenty-two milligrams of nicotine present.

Several investigators have undertaken the problem of the nicotine content of tobacco smoke and the amount absorbed on smoking.^{21,22} Baumberger,²³ from his study, concludes that an average of 0.573 per cent. of the weight of cigarette tobacco appears as nicotine in the smoke. Applying this figure along with the consideration that about two-thirds of a cigarette is smoked shows $1.0 \text{ by } .66 \text{ by } 0.573 = 3.78$ milligrams of nicotine appearing in the smoke of a cigarette. From a further study Baumberger²⁴ concludes that 66.7 per cent. of the smoke of tobacco is retained in the subject on puffing, and 88.2 per cent. on inhaling. He assumes that it is undoubtedly true that nicotine and total smoke would be retained in the same proportion and that therefore 66.7 per cent. of the nicotine would be absorbed in puffing and 88.2 per cent. on inhaling. Applying these figures the nicotine theoretically absorbed from the smoking of two-thirds of one cigarette on puffing would be 66.7 per cent. of 3.78 milligrams = 2.52 milligrams and by inhaling 88.2 per cent. of 3.78 milligrams = 3.33 milligrams.

Nicotine has been given in small amounts by mouth²⁵ without untoward symptoms. Absorption from the respiratory tract is definitely a more direct route to the general circulation than from the gastro-intestinal canal. With the question of the rate of absorption from the stomach and upper intestines there is also the claim that there is some destruction or detoxification of nicotine in the liver.²⁶ An intravenous administration to the general circulation more closely approximates the respiratory-tract absorption.

Under the conditions of the smoking experiment a total of six milligrams of nicotine hydrochloride was given by mouth at the rate of one milligram in thirty cubic centimetres of water at ten-minute intervals to

two young adult smokers and one non-smoker. Other than a mild irritative effect in the mouth and pharynx there were no symptoms. The blood-pressure, pulse and skin-temperature changes noted on smoking did not occur. We were convinced that minute quantities of nicotine could be given intravenously to smokers with safety. Solutions were prepared containing 0.1 milligram of nicotine tartrate or the alkaloid in one cubic centimetre of physiological saline. In order to obviate the psychic factor responsible for the momentary peripheral vasoconstriction incident to the puncturing of the vein for intravenous medication, a two-way valve was added

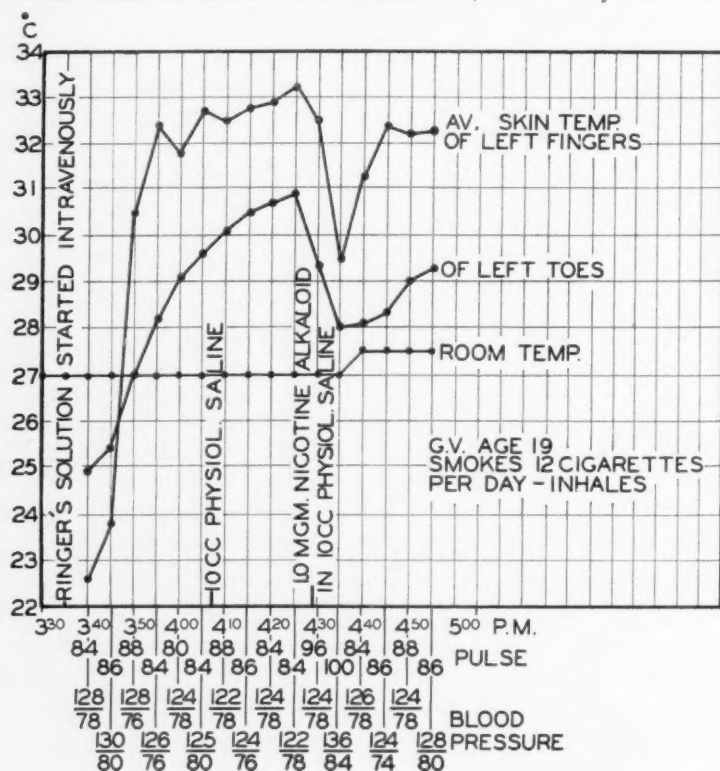


FIG. 3.—The effect of a 1.0 milligram of nicotine given intravenously on blood-pressure, pulse rate and peripheral skin temperature.

to the needle attachment of the burette used for the administration of intravenous fluids. Under our standard conditions Ringer's solution was then given intravenously in the left arm at the rate of 150 to 200 cubic centimetres per hour. As the subject became accustomed to the procedure the peripheral skin temperature rose to a fairly constant level. The valve was then turned and as a control ten cubic centimetres of physiological saline were slowly injected. The Ringer's solution was continued for a few minutes and then the nicotine was injected and followed by Ringer's solution to the end of the experiment. The data obtained from subject G. V. (Fig. 3), show that on the intravenous injection of one milligram of nicotine there occurred an

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increase in blood-pressure and pulse rate and a decrease in the skin temperature of the fingers and toes. As in the case of subjects smoking, the effect of the nicotine on the peripheral skin temperature was of longer duration than the effect on the pulse rate and the blood-pressure. Also, the skin temperature of the toes showed a slower rise towards their previous level than the case with the fingers. In Table II the results obtained with the four subjects of this study are presented.

TABLE II
Nicotine Intravenously

Subject.....	F.B.	H.G.	G.V.	H.L.
Age.....	33	18	19	45
	C.	C.	C.	P.
Average smoking per day, cigarettes or pipefuls.....	10	20	12	15
Total nicotine tartrate or alkaloid administered in mgms.	6	3	1.5	5
Increase in systolic B.P. in mm. of Hg.....	16	14	12	12
Increase in diastolic B.P. in mm. of Hg.....	4	2	6	4
Increase in pulse rate per minute.....	8	36	16	8
Decrease in av. skin temp., fingers °C.....	4.5	3.5	3.5	2.0
Decrease in av. skin temp., toes °C.....	1.5	0.5	2.7	1.2
Increase in rate and depth of resp. with each administration of nicotine.....	+	+	+	+
Mild aching in left arm.....	0	+	+	0
Mild vertigo.....	0	+	0	+
Peculiar taste in mouth.....	0	+	+	0

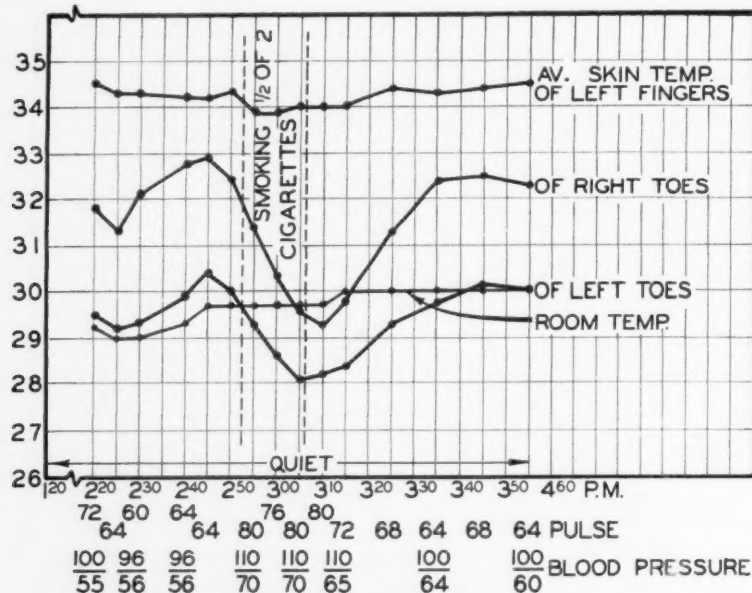
The nicotine administered intravenously was not greater than that theoretically absorbed from the smoking of two cigarettes. The data obtained show blood-pressure, pulse rate and skin-temperature changes fairly analogous with those of the normal subjects of Table I. This would tend to bear out in man the contention of Lee, Cushny, Sollmann and others that the effects of tobacco are due practically to its nicotine content.

Thrombo-angiitis Obliterans.—The application of this investigation to patients with thrombo-angiitis obliterans was carried out with considerable interest.

In Fig. 4 is shown the result of our study on F. S., aged fifty years, whose symptoms began fifteen years previously with intermittent claudication of both legs. He stated that from 1924 to 1929 he had smoked about ten cigarettes and two cigars a day. His general course had been periods of remissions and exacerbations of the intermittent claudications, always worse in the left leg, and with occasional periods of rest pain. No ulcerations or gangrene had developed. General physical examination was essentially normal, excepting the lower extremities. Both legs and feet showed some atrophy of the soft tissues. There was pallor of the feet on elevation and rubor on dependency, both being more marked on the left. Lower extremity pulses were:

	<i>Right leg</i>	<i>Left leg</i>
Popliteal artery.....	Fair	Slight
Posterior tibial artery.....	Fair	Slight
Dorsalis pedis artery.....	Fair	Slight

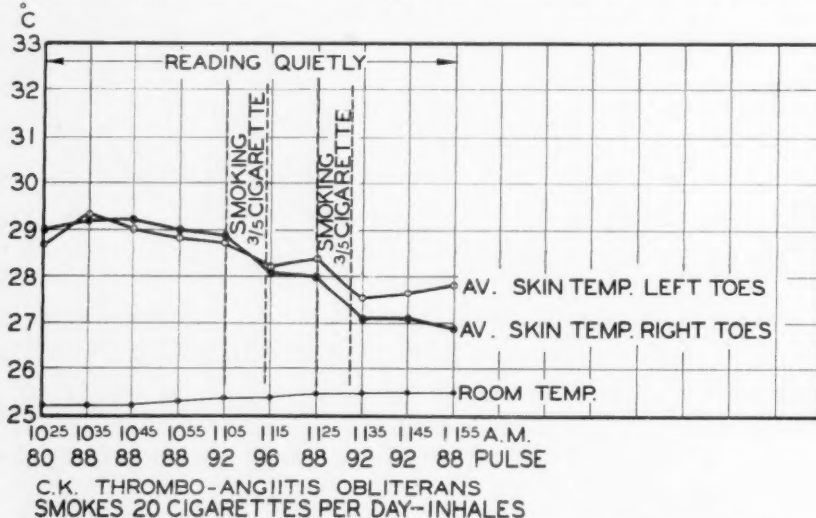
As a result of smoking under the same conditions used for the normal subjects this patient showed a marked decrease in the skin temperature of the toes and an increase



**F.S. THROMBO-ANGIITIS OBLITERANS
SMOKES 12 CIGARETTES PER DAY-INHALES**

FIG. 4.—Cigarette smoking producing an increase in blood-pressure and pulse rate and a decrease in peripheral skin temperature (peripheral vasoconstriction) in a patient (F. S.) with thrombo-angiitis obliterans.

in blood-pressure and pulse rate. Remembering that clinically the vascular deficiency was greater in the left foot than in the right, we found it to be in accord that the skin



**C.K. THROMBO-ANGIITIS OBLITERANS
SMOKES 20 CIGARETTES PER DAY-INHALES**

FIG. 5.—Cigarette smoking, with the patient sitting in a chair and reading quietly, producing an increase in pulse rate and a decrease in peripheral skin temperature (peripheral vasoconstriction).

temperature of the left toes throughout the experiment was lower than that of the right. Also considering that there were probably fewer uninvolved branches of the vascular

TOBACCO AND THROMBO-ANGIITIS OBLITERANS

bed in the left foot capable of constricting, it was reasonable that, on smoking, the decrease in the skin temperature of the left toes, of approximately 2.4°C ., was less than that of the right toes of 3.5°C . From the onset of smoking the skin temperatures of the toes did not return to their previous level for approximately forty-five minutes. Comparatively, there was a much greater response in the toes of this individual over the fingers than was observed in the normal subjects. Interestingly, it was noted that although this man tried to minimize his tobacco consumption by stating that he smoked only half of each cigarette we have never seen a subject inhale the smoke as deeply as in his case.

With a second case of thrombo-angiitis obliterans, C. K., the study was carried out under slightly different circumstances. Clinically, the extent of the vascular impairment in each leg was about equal. The patient wearing flannel pajamas sat in a comfortable chair with his legs resting on a low stool. His feet were uncovered. At the beginning of the experiment he started to read a magazine article and was told to smoke when and as he desired. Quietly, skin temperature measurements of the toes were recorded and pulse counts were taken from the right wrist. In Fig. 5 are shown the decreased peripheral skin temperatures and increased pulse rate incident to smoking.

Comment.—This study made on the effect of tobacco smoking, largely in the form of cigarettes, on young adult smokers, demonstrated a consistent increase in blood-pressure and pulse rate and a decrease in the skin temperature of the fingers and toes. Control experiments gave definite evidence that these effects were due to active products absorbed from the tobacco smoke. Nicotine administered intravenously in quantities not greater than that theoretically absorbed in the smoking of one or two cigarettes produced comparatively analogous changes. Greater effects were noted when the subject "inhaled" while smoking rather than merely "puffing," and also with rapid smoking more than with slow smoking.

The decrease in the peripheral skin temperature on smoking must be due to increased vasoconstriction. In a previous article¹³ we pointed out the value of measurements of the skin temperature of the fingers and toes under well-controlled conditions as indications of stimulation or depression of the sympathetic nervous system. In this study the decrease in the peripheral skin temperature was shown to be carried out through that system. While the peripheral vasoconstriction on smoking was usually measured only in the fingers and toes, the points of maximal response to changes in peripheral vasomotor tonus,¹³ it is undoubtedly true that vasoconstriction of skin vessels occurred to a lesser degree over the entire body.

By increasing peripheral vasoconstriction smoking reduced the blood supply of the fingers and toes of the young adults studied. With several subjects the reduction lasted more than thirty minutes from the time of cessation of smoking and generally was of longer duration in the toes than in the fingers. In the two cases of thrombo-angiitis obliterans cited, smoking produced the same cardiovascular response as in the normal subjects. The already deficient circulation in the feet of these two patients was further reduced by smoking, the decrease in F. S. (Fig. 4) lasting forty-five minutes.

We do not offer the data presented by this investigation as evidence that tobacco smoking is the etiological factor in thrombo-angiitis obliterans. The

occurrence of the disease in individuals who have never smoked precludes that opinion. It is interesting, however, to recall that other vasoconstricting substances, pituitrin²⁷ and particularly ergot, have been responsible for peripheral vascular occlusions and gangrene. Recently Kaunitz²⁸ pointed out the pathological similarity of thrombo-angiitis obliterans and endemic ergotism. In regard to marked vasospasm of neurogenical origin, Spurling, Jelsma and Rogers²⁹ demonstrated organic vascular changes in the fingers of a patient with long-standing Raynaud's disease. We have no doubt but that prolonged or marked vasoconstriction for a sufficient period of time may initiate organic vascular occlusions. The changes may occur not only in peripheral arterioles, capillaries and venules but also in peripheral arteries and veins as a result of zones of poor nutrition in their walls through vasoconstriction of their vasa-vasorum.

The criterion of a satisfactory result in the treatment of thrombo-angiitis obliterans is the avoidance of amputations and the return of the individual to his occupation. Every effort towards that ideal is based on the principle of increasing the peripheral circulation. The demonstrated vasoconstrictor effect of tobacco smoking would lessen or nullify the benefits of all conservative treatment. The experimental data presented form a rational basis for the clinical conclusions as to the deleterious influence of tobacco smoking on the progress of thrombo-angiitis obliterans. Its use definitely further decreases the already deficient circulation in the extremities of the individuals with that disease. We unhesitatingly counsel against tobacco smoking by patients with thrombo-angiitis obliterans.

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BASIS FOR RECURRENCE OF VARICES IN THE VARIOUS FORMS OF THROMBOPHLEBITIS

BY FRANK V. THEIS, M.D.

OF CHICAGO, ILL.

FROM THE DEPARTMENT OF SURGERY OF RUSH MEDICAL COLLEGE

THROMBOPHLEBITIS of varicose veins as ordinarily observed by the surgeon is seldom followed by permanent obliteration. Clinical experience with post-operative, traumatic, infectious and so-called spontaneous thrombophlebitis has firmly convinced him that recurrence of the varices is to be expected. In a few weeks to a few months the veins are seen to reopen with a return of circulation. In fact, thrombophlebitis is frequently accepted as an etiological factor¹ in varicose veins. Nevertheless, a clinically indistinguishable form² of thrombophlebitis produced by the injection of chemical irritants has been found highly satisfactory in permanently occluding varicose veins. The results of my own injection cases during the past four years compare very favorably with the 6 to 15 per cent. of recurrences in the thousands of cases reported by Kern,³ McPheeters,⁴ Kilbourne,⁵ Foresteir,⁶ O'Neill⁷ and de Takats.⁸ However, the gratifying results of these experienced men are questioned because of a report in which 98 per cent. of sixty-six cases of varices recurred within one year following the injection treatment.⁹ Phleboliths and fibrosed veins are sufficient pathological evidence that veins are permanently obliterated by a thrombophlebitic process. The adverse criticism occasioned by the reported 98 per cent. of recurrences following injection stimulated the present investigation.

In any case of thrombophlebitis the likelihood of recurrence depends upon recognized physiological principles. The tremendous material now concentrated in the medical centres interested in varicose veins affords unusual opportunity for detailed investigation. The following report of clinical observations and pathological study of a large series of various forms of thrombophlebitis was undertaken to establish a basis for: (1) Determining the probability of recurrent varices in any given case; and (2) improving the efficacy of obliterating varicose veins permanently by a chemically induced thrombophlebitis.

Nature of Thrombophlebitis.—Phlebitis or thrombosis may occasionally occur alone, but, as usually observed, one precedes the other.¹⁰ The resulting clinical picture may include a periphlebitis¹¹ with redness, swelling, tenderness and increased temperature along the course of a hard thrombosed vein. This may vary according to the size of the vessel and the intensity of the inflammatory reactions. Irrespective of the etiological factor for the thrombophlebitis the same physiological basis for the thrombosis and the same pathological basis for the phlebitis is usually responsible. In the present

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discussion I assume that the condition of the blood and circulation is within normal limits. In general, a damaged intima from whatever cause predisposes to thrombosis, and bacterial organisms or chemical toxins to phlebitis. A knowledge of these fundamentals is essential to understand the basis for recurrences of varicose veins.

The primary reaction of blood at the site of ruptured, damaged, or destroyed intima is the liberation of a ferment activating thrombus formation.¹² MacCallum,¹³ Aschoff,¹⁴ and Kaufmann¹⁵ state that the "wall of the vessel underlying a thrombus is always injured." At least some interruption of the intima is essential except where clotting is induced by a coagulant¹⁶ and even in these cases the intima is probably injured. I have observed in experimental work that a loosely ligated vessel does not ordinarily become thrombosed.¹⁷ Only when the ligature is applied with sufficient force to break the intima can an obliterating thrombus be expected. When the endothelium is injured by external trauma such as a contusion or ligation, or by internal trauma as infection or injection of chemical irritants, the same physiological process of thrombus formation follows. Activity of the circulation then determines whether a stagnant red clot or a white (or mixed) thrombus will result. The red thrombus is composed of the component parts of the blood in their normal proportions and is somewhat similar to clotted blood *in vitro*.¹⁸ A white thrombus formed in an active circulation is selective in character, in that the platelets predominate with the leucocytes. These platelets are the forerunners of fibroblasts and connective tissue, which ultimately produce fibrosis of the vessel. Buerger¹⁹ quotes experimental results to show that "when a vessel is ligated no platelet formation could be observed even after the use of caustic irritation, while a typical platelet thrombus develops under such condition in a vessel in which the blood circulates." Many of the contributors to the literature on varicose veins fail to consider this physiological principle. Reclining inactive position, ligation, tight pressure bandages are conducive to stagnation and directly interfere with mixed thrombus formation. Instead, a red stagnant thrombus develops which may be absorbed due to the proteolytic action of disintegrating leucocytes. Other factors being equal, more rapid recurrences occur therefore, in post-operative, bacterial, ligation, and injection thrombophlebitis where the activity of the circulation has been retarded.

The origin of the concomitant phlebitis is a matter of considerable dispute. Ordinarily bacteria can be found only in the frank suppurative cases. Of course, it is easily conceivable that a bacteræmia may result in bacteria lodging in a thrombus or in the vasa vasorum and thereby produce the phlebitis. However, it is difficult to believe a bacteræmia and thrombosis to be simultaneously present in such a large majority of cases. The fact remains that in most instances, the exciting organism cannot be isolated. Frazier²⁰ believes that infection is surely present although the bacteria may have been destroyed or may be of too low virulence to be isolated. Extensive phlebitis is seen following injection of chemical irritants or ligation of veins.

It occurs so generally in certain types of very large veins that I cannot attribute its occurrence to a lack of asepsis. Skin incisions for ligation of varicose internal saphenous veins are almost invariably very slow in healing and have every appearance of a low-grade infection.

Homans' outstanding contributions²¹ on thrombophlebitis and lymphangitis stress as important the fact that the lymphatic vessels follow very closely the course of the large venous trunks. Kaufmann maintains that phlebitis is a lymphangitis of the vein wall. The lymphatic channels in the lower extremities constantly convey organisms from the toes, feet and leg to the groin although their presence or source may not always be apparent. The marked tortuosities and dilatations of varicose veins contribute to stagna-

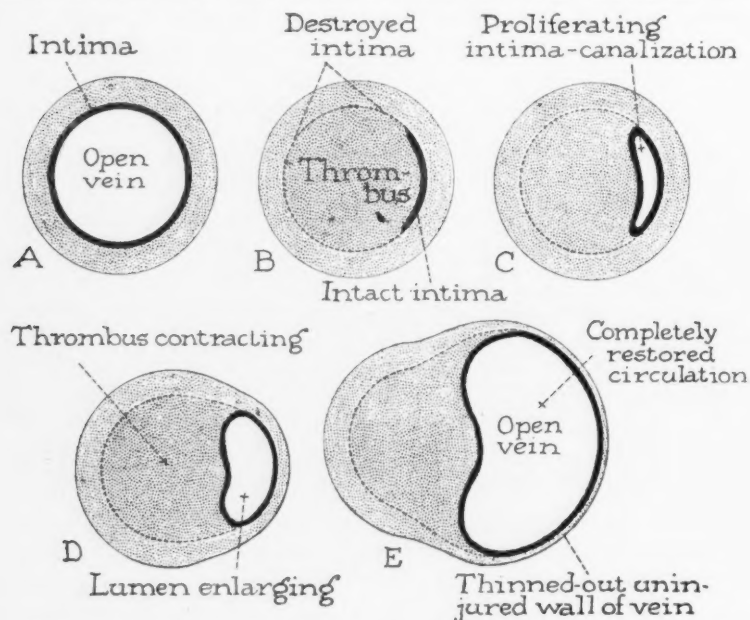


FIG. 1.—Diagrammatic explanation of reopening of lumen of a thrombosed vessel: A—Normal vein with intact intima. B—Partial intima destruction with thrombosis. C and D—Proliferating endothelium of intima and contraction of the thrombus away from the uninjured wall of the vein enlarges the recurrent lumen. E—Lumen of vein larger than normal due to the stretching of the thinned-out uninjured wall by the restored circulation. Remainder of old vein replaced by contracted fibrous tissue is seen at the left of the new lumen.

tion of the blood circulation and subsequent lowered resistance of the surrounding tissues. A similar disturbance of lymphatic circulation exists with stored-up latent infection. Swelling, induration, fibrosis, eczema, ulceration and infection are therefore prone to occur in these tissues. I am convinced that the same factors, such as trauma, ligation, or injection of chemical irritants, responsible for damaging the intima of the vein, simultaneously activate the latent infection²² in the accompanying lymphatics. This results in the clinical picture of thrombophlebitis. Clinical experience confirms such a course of events with gradual subsidence of the inflammatory reaction.

Subsequent Fate of Thrombosis.—The primary obliterating thrombus in every case soon contracts. This contraction is inseparable from fibrin forma-

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tion and occurs whether the clot is in a blood-vessel or in a test tube. With firm attachment of the thrombus to the vessel wall a puckering of the vein and overlying skin is commonly observed; and when insufficient attachment is present, the contraction will leave a space between the wall and the thrombus. (Fig. 1.) Rapid recurrence of varices after thrombophlebitis can be definitely attributed to a shrinking away²³ of a thrombus from the vessel wall. (Fig. 2.) Proliferating endothelium then covers the exposed surface of the thrombus so that the lumen of the vein is reestablished.

Partial or complete absorption of thrombi occurs due to the proteolytic action of disintegrating leucocytes.²⁴ The larger the proportion of leucocytes present in a stagnant or infectious thrombus the more frequent and rapid will



FIG. 2.—Photomicrograph illustrating E in Fig. 1. The restored endothelial lined lumen is filled with blood. The contracted fibrosed thrombus is seen to one side.

be the absorption. Conversely, a selective platelet or mixed clot uncomplicated by infection is less likely to undergo this process. No doubt, many cases of recurrence of varices following thrombophlebitis can be explained on this basis.

Organization of thrombi with or without canalization is the only alternative of absorption. The time required for the changes in the thrombus to take place in this stage is variable. Such factors as the condition of the circulation, general condition of the patient are in the present discussion presumed to be within normal limits. The process of organization involves fatty degeneration and necrosis of the leucocytes, decolorization of the red corpuscle and absorption of the hæmoglobin, and finally replacement of the platelets by fibrous deposits. Accordingly, absence of proteolytic ferments

and the predominance of platelets in a white clot furthers fibrous replacement of a clot. This fibrosis occurs as an ingrowth of vascular granulation tissue from the sub-endothelial connective tissue. As this becomes dense and in the complete absence of intima, contraction of the fibrous tissue will permanently obliterate the vessel. Deposition of lime salts leads to phlebolith formation.

Canalization of an organizing thrombus proceeds from the site of intact intima. Even the report from Holman's clinic²⁵ discrediting the possibility of obliterating veins permanently by means of a thrombophlebitis fully describes and illustrates recurrences as proceeding from uninjured intima. Solid buds of proliferating endothelium grow into a thrombus, open to



FIG. 3A.



FIG. 3B.

FIGS. 3A and B.—Excised specimens of old fibrotic internal saphenous vein from the site of injection three years previous. (A)—Photomicrograph showing complete fibrosis and a few endothelial lined capillaries. (a) In serial sections these capillaries were non-continuous and some appeared as blind bloodless areas. Absence of intima accounts for the permanence of the obliteration.

form a lumen, and becoming confluent reestablish the lumen of the vessel. Both Kaufmann and Aschoff emphasize the importance of intact intima for organization and canalization. Naturally, the more intima that remains uninjured in the presence of a thrombus, the more rapidly will canalization and recurrence of the varices proceed. With the intima completely destroyed around the entire circumference of a vein for a considerable distance, reopening of the lumen by this process is not likely. However, isolated blind and bloodless endothelial-lined spaces may be frequently observed microscopically in old fibrosed thrombi. These are easily misinterpreted and reported as canalization unless serially studied or grossly examined. These spaces are due either to non-communicating capillaries supplying the scar tissue or to the metamorphosis of lymphocytes²⁶ to fibroblasts and then to endothelium.²⁷ There is a wide difference of opinion among

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investigators as to the source of endothelium and fibroblasts. Fig. 3A illustrates such findings in a thrombus three years old and the spaces are not continuous in serial sections. Probability as to the permanency of obliteration in an organizing thrombus depends largely upon the extent and completeness of intima destruction. The time required and the degree of recurrence of varices in clinically indistinguishable forms of thrombophlebitis therefore varies.

Critical Analysis of the Common Types of Thrombophlebitis.—As to the possibility of recurrences of varicose veins: With a knowledge of the aforementioned clinical and experimental facts a better idea may be had as to what end-results may be expected in any case of thrombophlebitis. I will briefly correlate these facts in explaining recurrences in the most commonly observed etiological forms of thrombophlebitis.

Post-operative Thrombophlebitis.—Ligation or clamping of bleeding vessels especially as is seen following pelvic operation²⁸ may be the point of origin of extensive thrombosis. Contusion of varicose veins in handling the patient or in the course of the operation may likewise cause a limited interruption or damage of endothelium with resulting thrombophlebitis during convalescence. The presence of an inactive circulation with stasis of the blood in the large veins due to the patient being confined to bed furthers extension of the thrombus. Consequently, a typical red clot develops which usually undergoes rapid absorption or organization. The possibility of infection except in suppurative cases is not so great as is generally believed although a bacteræmia or contamination at operation may produce an infection of the vessel wall. This will be considered under infectious thrombophlebitis. Canalization of the thrombus proceeds by proliferation and ingrowth of abundant uninjured endothelium underlying the thrombus. In general, therefore, this form of thrombophlebitis is followed by early recurrence of the varices.

Bacterial Thrombophlebitis.—Organisms, from a bacteræmia or from the surrounding tissues, may destroy sufficient intima for thrombosis to occur. Confinement of the patient to bed contributes to red thrombus formation. The infection still further increases the number of leucocytes in the developing thrombus. Proteolytic action of the numerous degenerating leucocytes produces rapid absorption of the thrombus. Recurrences of varicose veins are seen within two to four months.

Ligation Thrombophlebitis.—Ligation of varicose veins as an adjuvant to the injection treatment of veins has become quite popular. De Takats²⁹ has been especially enthusiastic regarding this practice although Linser,³⁰ in the course of 50,000 injections, writes disapprovingly of its use. McPheeters³¹ also objects to ligation and believes that it contributes to failures in the injection treatment. I have observed a number of ligation cases operated by a colleague where in spite of subsequent injections, recurrences of veins commonly occurred. (Fig. 4.) The limited break in the intima due to the ligature gave rise to thrombus formation, but the coincident retarded

circulation contributed to red thrombus formation and rapid absorption. No doubt recurrences are delayed by the ligation but the lack of extensive intima destruction provides sufficient endothelium for proliferation and canalization to occur. Therefore, both absorption and canalization may be expected to hasten recurrences.

So-called Spontaneous Thrombophlebitis.—No etiological factor can be

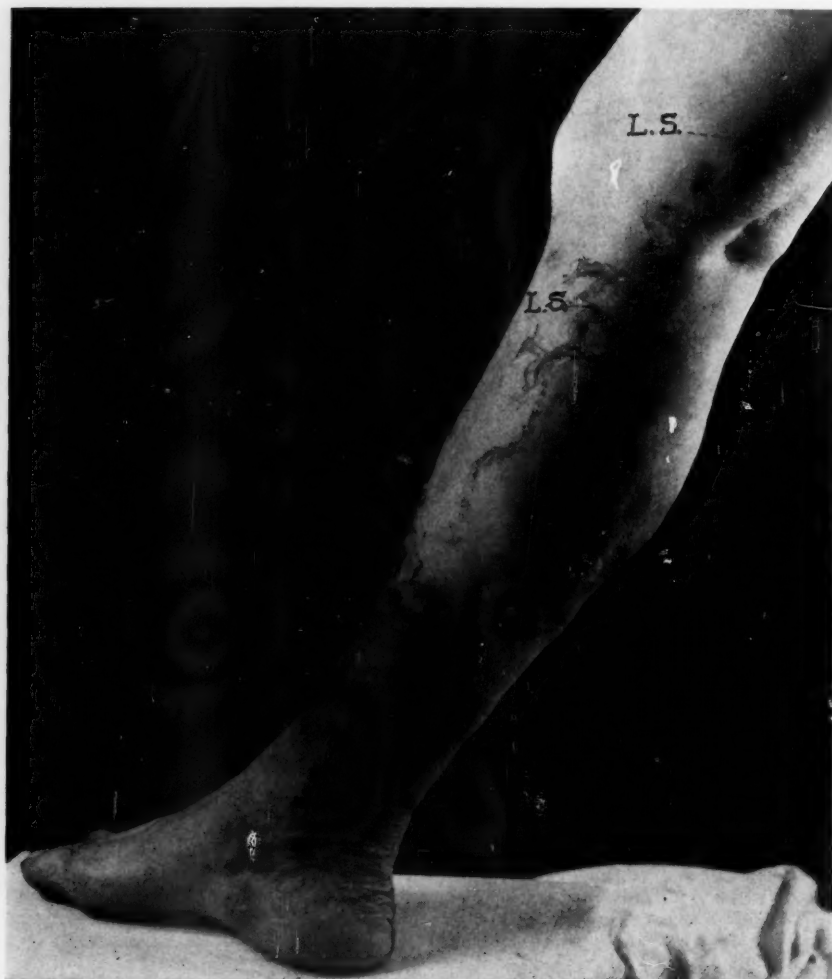


FIG. 4.—Reopened veins following ligation thrombophlebitis (six months). The site of the ligation scars (L. S.) is apparent.

found to explain the occurrence of many cases of thrombophlebitis³²; the absence of any definite cause places these cases in this category. No doubt damage of the intima predisposed to the condition irrespective of whether or not a cause could be found. Theoretically, a healthy individual may have a transitory bacteræmia without its presence being manifest. Also a slight trauma to the poorly nourished tissues around varicose veins may pass un-

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noticed. However, the intima damage when the cause is undeterminable is, very likely, limited in extent so that sufficient endothelium remains for proliferation and rapid recurrence of veins. Incapacitating the patient results in red thrombus formation, which further hastens the disappearance of the primary obliterating thrombus by absorption.

Chemically Induced Thrombophlebitis for Permanent Obliteration of Varicose Veins.—Numerous chemical irritants are advocated for injection into varicose veins to damage sufficiently or destroy the intima for thrombosis to follow. These include hypertonic sodium chloride, sodium salicylate, quinine and urethane, dextrose, levulose-dextrose and sodium morrhuate. Each has been enthusiastically reported in the literature as superior to the others. However, the primary object of any of them is to destroy the intimal lining of the vein. Limited damage³³ of the intima may be followed by a primary obliterating thrombus but its occurrence cannot be held as a criterion as to the permanency of the obliteration. The technic of injection must assure extensive loss of endothelium which is uncertain in the presence of blood dilution. The advocates of the powerful necrosis-producing solutions such as hypertonic sodium chloride or sodium salicylate report a greater percentage of primary obliterating thrombi because these solutions do not require that the veins be completely bloodless. Still, the danger of necrosis and severe pain makes the necessary technic for injection less certain of extensive intima destruction. The less powerful solutions such as the dextrose or levulose-dextrose require a bloodless area but the solution can be safely held in contact with the intima long enough to assure adequate intima damage. The successful use and efficacy of the sugar irritants depend upon the skill and technic employed, as has been fully described elsewhere.³⁴ The more completely the intima is destroyed the more certain will the primary thrombus permanently obliterate the vessel.

The type of primary thrombus formation is determined by the activity of the circulation. Since we recognize the importance of a platelet thrombus in order to avoid proteolytic absorption the circulation must not be retarded. Adjuvant ligation pressure bandages, recumbent position, elastic bandages, although recommended procedures, directly interfere with the desired platelet thrombus formation. Therefore, the activity of the patient should be encouraged after injection and during the time that complete occlusion thrombosis of the vessel is taking place.

SUMMARY.—The two essentials for determining the permanency of obliterating thrombophlebitis are (1) the extent and completeness of the destroyed intima predisposing to the primary thrombus formation, and (2) the type of the primary obliterating thrombus.

Extensive destruction of the entire circumference of the intima is essential for thrombophlebitis to obliterate varicose veins permanently by the process of organization without canalization. For injection treatment of varicose veins the technic employed, rather than the solution used, is of greatest importance to achieve such destruction.

Proliferating uninjured intima, where only localized damage has led to thrombosis, will restore the lumen of the vessel. This is the normal physiological process of organization and canalization and is the basis for recurrences in most cases of thrombophlebitis. A stagnant red clot may undergo rapid absorption. Ligation, recumbent position, pressure bandages, or elastic stockings retard the circulation in varicose veins, thereby furthering the formation of stagnant red thrombi.

Activity of the circulation during thrombus formation furthers the development of a white or mixed platelet thrombus. This type is most likely to produce permanent fibrous obliteration of the vein.

Microscopical study of biopsy sections of obliterated veins should take into consideration the site of origin of the thrombus. At a distance from this point the intima is not disturbed and proliferation of the intact intima produces canalization of the thrombus. Permanence of obliteration of varicose veins by means of the injection treatment must be studied from sections removed at the site of the injection of the chemical irritant.

CONCLUSIONS

Post-operative, infectious, ligation and so-called spontaneous thrombophlebitis are usually followed by organization and canalization of the thrombus with restoration of the lumen of the vessel. The limited damage to the intima causing thrombus formation and confinement of the patient to bed influences the rapidity of recurrences of veins.

Annular and extensive intima damage in chemically induced thrombophlebitis is necessary for permanent obliteration of varicose veins. Otherwise retraction of the thrombus away from the undamaged wall or proliferation of uninjured intima will restore the lumen of the vessel.

When recurrences are observed another injection at that site should assure destruction of the remaining intima.

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RENAL NEOPLASMS

REPORT BASED UPON TWENTY-FIVE CASES OF MALIGNANT TUMORS
OF THE KIDNEY

BY JOSEPH A. LAZARUS, M.D.
OF NEW YORK, N. Y.

THERE are few chapters in urology that are quite as discouraging to the surgeon as the chapter dealing with malignant tumors of the kidney. While malignant tumors occurring anywhere in the body, when considered as a group, give therapeutic results that are far from satisfactory, it is difficult to understand why neoplasms of the kidney offer such dismal prospects as regards end-results following their extirpation. Until such a time when the true causative agent of new growths is ascertained, any advance in the treatment of these lesions must of necessity depend upon bits of information obtained from the clinical observations of physicians actually engaged in treating such cases. Statistical analyses of groups of cases, regardless of their size, coming from clinicians sufficiently interested to carefully record their observations, procedures and results must eventually serve to throw some additional light upon the subject which is at present engaging the patience, skill and ingenuity of cancer research workers the world over. It is for the purpose of placing upon record observations based upon a series of twenty-five malignant tumors of the kidney that this paper is presented.

CLASSIFICATION OF RENAL TUMORS

I.—Tumors of the Kidney Proper: (A) Involving Parenchyma. 1. Adenoma. (a) Cystadenoma. (b) Papillary adenoma (papillary cystadenoma). 2. Carcinoma. (a) Nodular forms. (b) Diffuse carcinoma. (c) Multiple carcinomata. (d) Lymphangitis carcinomatosis. (B) Involving Stroma. 1. Benign. (a) Lipoma. (b) Fibroma. (c) Myoma. (d) Angioma. 2. Malignant (sarcoma). (a) Spindle cell. (b) Embryonic Tumors:—(1) Adenomyosarcoma. (Birch-Hirschfeld.) (2) Adeno-myochondrosarcoma. (Wilms.) (3) Teratoma. (C) Hypernephroma. 1. Benign. 2. Malignant. (Grawitz.)

II.—Tumors of the Renal Pelvis. (A) Of Epithelial Origin. 1. Papillary carcinoma. 2. Prickle-cell carcinoma. (B) Of Connective-tissue Origin. 1. Lipoma. 2. Lymphangioma. 3. Fibrosarcoma.

Although some writers classify cysts along with renal neoplasms, they are purposely omitted in this outline because of the fact that the writer considers them as due to retention resulting from inflammatory changes, or to congenital defects rather than to actual metaplastic or hyperplastic cellular changes.

Adenomata.—Renal adenomata are more of academic interest than of clinical importance. They usually occur in groups in the renal cortex in older

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individuals and give rise to no symptoms. Histologically they appear as clusters of epithelial cells arising from the renal tubules with or without acini. They are white, brown or yellow in color and vary from pea size to the size of walnuts. Occasionally, they undergo cystic changes and are then designated as cystadenomata. They frequently are seen in contracted kidneys. Some of these tumors show papillary tendencies and are then designated as papillary adenomata or as papillary cystadenomata. Papillary adenomata frequently undergo fatty and malignant changes as a result of which they carry a poorer prognosis than do the cystadenomata.

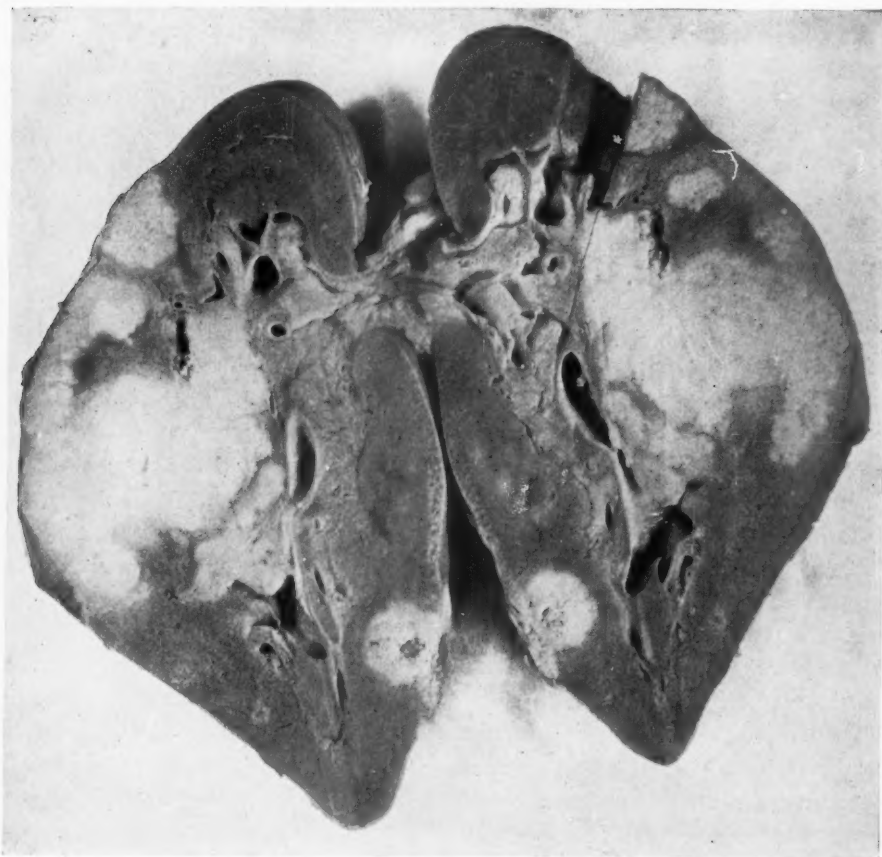


FIG. 1.—Squamous-cell carcinoma. Sagittal view of kidney.

Carcinoma.—Primary renal carcinomata arise from the epithelial cells of the tubules or of Bowman's capsule, usually occur in one kidney and are not infrequently associated with calculi. These tumors may appear in a variety of forms. The nodular form designated by the Germans as "Knotformen" usually results from renal adenomata which have undergone malignant change. When the carcinoma arises from the tubular epithelium, it spreads diffusely through the renal parenchyma, giving rise to a large kidney, and shows a marked tendency toward infiltration. Such tumors undergo regres-

sive changes such as fatty degeneration, hæmorrhages, calcification and necrosis, which explains the frequent occurrence of cysts within them. Such a tumor bears the designation of diffuse carcinoma of the kidney, or, as the Germans call it, "carcinoma adenomatoides," because of the tendency of the tumor-cells to arrange themselves in pseudo-gland formation. Multiple carcinomata of the kidney are usually secondary or metastatic. They occur as round tumors in the cortex and histologically are of similar construction to the parent growth. (Fig. 1.)

There is a type of carcinoma designated as "lymphangitis carcinomatosa" which is of unusual clinical significance. In this type of involvement, the kidney is secondarily invaded from a primary lesion situated in a neighboring organ such as the stomach or retroperitoneal lymph-nodes, the extension proceeding along the course of the lymphatic channels. It is of interest to note that in the kidneys the lymphatics are closely attached to the walls of the veins but not the arteries, so that in looking for evidence of this type of renal invasion, special attention should be paid to the main venous channels of the kidneys and particularly to the arcuate veins.

Tumors of Connective-tissue Origin.—The benign group of connective-tissue tumors are of little importance. Lipomata of the renal capsule are common and may attain large size; while those occurring in the renal substance are very rare, usually congenital and appear as small yellow tumors most frequently situated in the cortex. Not infrequently they occur as mixed tumors, namely as lipomyomata or as liposarcomata. Fibromas are also common and appear as small, round, whitish, elastic, homogeneous nodules situated in the cortex or medulla. Myomata are most frequently found in the medulla, while the angioma which is exceedingly rare is found on the outer surface of the kidney and usually associated with malignant tumors involving that organ.

The malignant variety constitutes an interesting and important group of renal neoplasms. The majority of them are of congenital origin and occur most frequently among children. They may grow to enormous size and displace most of the abdominal viscera. In appearance these tumors are whitish or pinkish in color, of soft consistency and rich in blood-vessels. Although occurring in adults, the spindle-cell and round-cell sarcomata are also encountered in children. Occasionally they occur in combination with adenomata and are then designated as adeno-sarcoma. The group of embryonic tumors consisting of the adeno-myosarcoma (Birch-Hirschfeld), adeno-myochondrosarcoma (Wilms), and the teratoma occurs practically always in infants and young children. As indicated by their respective designations, they are all mixed tumors.

Various theories have been advanced to explain the origin of these mixed tumors, but the one that seems to bear the most credence is the theory maintaining the incorporation of a fragment of the somatic plate, especially that part which represents the anlage for spine, ribs and muscles into the anlage of the renal parenchyma, with subsequent malignant changes of one or more of the included components. At times these mixed tumors never actually

invade the renal parenchyma but rather grow into the hilus, pushing the kidney aside or invaginating the kidney as a fist would when pushed into a balloon. They show no tendency to invade the renal pelvis, as a result of which urinary symptoms are absent. Any component of the tumor may take on malignant properties, thus giving rise to sarcoma or carcimona, which explains the variation of structure of metastases from these mixed tumors, since the histological architecture of the metastases resembles the parts of the parent tumor which have undergone malignant change.

Hypernephroma.—Grawitz noted and described a round, circumscribed, well-encapsulated tumor varying in size from that of a cherry to the size of a walnut, of sulphur-yellow color and usually situated in the renal cortex, and designated it as "struma lipomatodes aberrata renis," believing it due to a congenital inclusion of an aberrant adrenal rest within the kidney substance (benign hypernephroma).

In contradistinction to this benign growth, which is of rare occurrence, there is a malignant tumor of almost identical histological architecture to the benign tumor which for many years has been known as hypernephroma. This tumor differs from the Grawitz tumor in its tendency to invade the renal vein and pelvis and to grow through its capsule. It is this growth which constitutes by far the vast majority of renal tumors and practically always occurs in adults. In size, the tumor varies from that of a nut to the size of an adult head, and shows a great tendency to hæmorrhage, necrosis and softening which accounts for its brownish and reddish discoloration, and also explains the frequency of cavitations within the tumor.

Microscopically, it is almost impossible to differentiate between the benign and malignant forms. Like the adrenal the architecture of this growth consists of a stroma rich in capillaries, and cords or groups of large polyhedral cells, many of which are rich in fat globules. Occasionally the strands of cells arrange themselves in ring formation, the lumina giving them the appearance of glands. Papillary formations are not uncommon. A pathognomonic feature of the malignant hypernephroma cell is its richness in glycogen. This is beautifully demonstrated by staining with best glycogen stain—the glycogen granules appearing red. When stained with iodine the granules turn brown—a reaction shown by no other cancer tissue. To obtain this reaction the tissue must not be soaked in water before staining, since water washes out the glycogen. The specimen is best immersed in alcohol. The foamy and transparent appearance of the cell protoplasm is due to its glycogen content.

A great diversity of opinion exists concerning the exact etiology of the malignant hypernephroma. Opposed to the theory advanced by Grawitz, and supported by Kostenko and others explaining the development of the tumor on the ground of adrenal inclusion, there are such observers as Stoerk, Sudeck, Lubarsch and others who maintain the nephrogenic origin of the growth, stating that the tumor arises from the tubular epithelium of the kidney and has nothing to do with the adrenal gland. Zehbe, for example,

while favoring the nephrogenic origin of this tumor, differs from Stoerk in maintaining that it represents a compensatory reaction on the part of the renal epithelium. In view of the absence of agreement as regards the etiology of the neoplasm, it seems best for the time being to designate the tumor as a nephroma rather than hypernephroma.

Clinical Course of Malignant Renal Tumors.—The chief outstanding feature of malignant renal tumors is their propensity of breaking into the renal vein so that at autopsy or operation one frequently sees a thrombotic plug laden with tumor-cells projecting into the renal vein and not infrequently into the vena cava. The sites of predilection for metastases which are very common in cases of hypernephroma and renal carcinomata are the lungs and liver. Such metastases can appear years after the extirpation of the primary focus. The skeletal system is not infrequently invaded by metastases from hypernephromata leading to spontaneous fractures and to compression of the spinal cord when the deposits are in the vertebral bodies. Regional lymph-nodes and brain are occasionally involved.

The presence of an associated hydrocele indicates a plugging of the spermatic vein by a malignant thrombus. Occasionally a varicocele may result from pressure of affected nodes or of the tumor itself upon the spermatic vein.

When the tumor breaks into the renal pelvis it makes its appearance there in the form of nodules or polyps which may block the ureteropelvic juncture and lead to the formation of a large hydronephrosis. Necrotic portions of the tumor may become calcified, detach themselves from the tumor mass and pass down the ureter as true concretions.

Invasion of adjacent organs such as the colon, adrenal and diaphragm may occur in the event the tumor breaks through its fibrous capsule. Such an occurrence is not at all infrequent in adults. In cases where tumors have grown to large size there occurs a displacement of intra-abdominal organs, particularly the ascending or descending colon, a condition readily discernible from abdominal examination.

Urinary changes may be entirely wanting in cases of renal tumors, especially in children, where the only symptoms are pain and the presence of a tumor. In the adult the chief outstanding symptom is hæmaturia. This symptom, according to Garré-Borchard (*Lehrbuch d. Chir.*, Leipzig, Vogel, 1920), occurs as an early symptom in 70 per cent. of cases. Attacks of renal colic may accompany hæmaturia in the presence of blood clots but as a rule the hæmaturia is painless. Local pain over the affected kidney was seen in 68 per cent. of the cases in this series and is usually a late symptom.

Diagnosis.—While the diagnosis of renal neoplasm is easily made in advanced cases, it may tax the skill, patience and ingenuity of even the most skilled urologists to diagnosticate the disease in its incipient stage. And yet, it is only in the early stages that diagnosis holds forth any hope of ultimate therapeutic success.

Realizing that hæmaturia constitutes the outstanding symptom of this

disease, varying from 70 per cent. (Garré-Borchard) to 84 per cent. in this series, it becomes incumbent upon the clinician to subject every patient that presents himself complaining of hæmaturia or showing the presence of erythrocytes in the urine to a thorough and painstaking examination in order to locate the source of the bleeding. To treat such a patient expectantly without properly evaluating this symptom is certain to court disaster. Twenty-four per cent. of the patients in this series applied for urological study one year or longer after the appearance of symptoms. This in itself is sufficient evidence that hæmaturia is not yet recognized by the general profession as a sufficiently important symptom to warrant a complete urological study. To those familiar with this type of disease, it is not unusual to have a patient state that his initial hæmaturia occurred two or more years prior to operation.

Assuming, then, that a patient presents himself with an initial attack of hæmaturia and is referred for urological study. To the urologist hæmaturia brings to mind four conditions of which hæmaturia is an outstanding symptom, namely: tumor, tuberculosis, stone, and so-called idiopathic hæmaturia (calyx-pyelitis). The presence of bladder ulcerations, a moth-eaten appearance of one or more of the calices on the pyelogram and tubercle bacilli in the urine suffice to clinch the diagnosis of tuberculosis. A renal calculus is easily recognized as a positive shadow on the flat plate or in the case of a uric-acid stone as a negative shadow on the pyelogram. In the late stages, with a typical spider deformity or filling defect in the pyelogram, neoplasm is easily diagnosed and often confirmed by the presence of a mass in the loin. In the early stages, however, great difficulty is encountered in making the differential diagnosis between tumor and so-called idiopathic hæmaturia. It is in just such cases that the skill and experience of the examiner are required, particularly in interpreting pyelograms. Upon the proper evaluation of a filling defect in a pyelogram, be it ever so insignificant, may depend the solution of a baffling case and the establishment of a correct diagnosis of a small renal tumor. Yet cases are seen by urologists of great clinical experience where the cystoscope establishes the presence of bleeding from one kidney and yet where repeated pyelograms fail to show any deviation from the normal, and where tuberculosis and stone can be positively eliminated. Just what is to be done in such cases? At times one may note, upon careful reading of a well-taken flat film, a bulge on the convex border of the renal silhouette (Case K. J., of this series) which will suffice to warrant operation on the suspicion of the presence of a renal tumor which has not as yet invaded the pelvis or calices. (Fig. 2.) A globular appearance or pear-shaped enlargement of one renal pole seen on the flat film may make the diagnosis, while not certain, at least tentative. Repeated cystoscopical examinations and pyelograms taken at short intervals must be resorted to in cases where unilateral hæmaturia has been found and where the diagnosis rests between tumor and idiopathic hæmaturia. Should no change occur in the urological findings after a lapse of approximately four months, it is the opinion of the writer that exploratory operation is indicated.

This brings up the question of renal exploration and the proper procedure to follow in the event that the surface examination of the kidney fails to disclose the presence of a tumor. Should the kidney be incised and explored or should it be removed? The risk involved in a splitting exploratory operation of a kidney is recognized by any experienced urological surgeon, and while it was a common procedure even up to a decade ago, it is now infre-

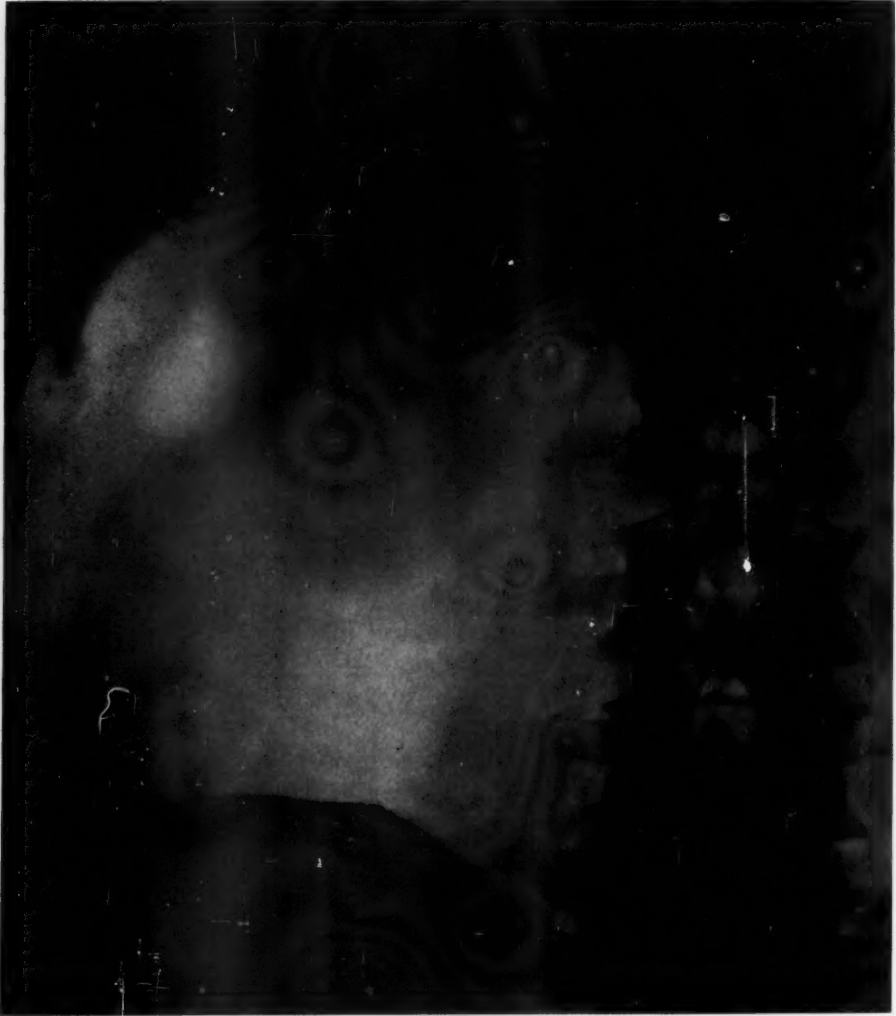


FIG. 2.—Flat plate. Note bulge on the convex surface of the kidney. (Operation—adeno-carcinoma.)

quently employed. This procedure is permissible, however, where on palpation of the kidney any suspicious induration is felt within the renal mass. Yet it is in just such a kidney where in spite of a splitting operation a minute tumor may escape detection and later may be ascertained at autopsy. It appears to the writer that in choosing between an exploratory splitting operation on a suspected kidney with negative findings and a nephrectomy on sus-

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picion that a tumor may be present, it is probably better judgment to follow the latter course, provided, of course, the other kidney has been found, prior to operation, to be capable of sustaining life.

Absolute diagnosis of so-called idiopathic hæmaturia which most recent investigation has shown to be due to an ulcerating pyelitis involving the terminal calices (calyx-pyelitis) (Ceelen) can be made by the process of elimination or by histological study of the extirpated kidney. Nephrectomy in such cases is done either upon the ground of mistaken diagnosis or for the purpose of preventing death from alarming hæmorrhage. Chagrin and regret have fallen to the lot of those surgeons who handle urological cases and who are unfortunate enough to have removed a bleeding kidney and to find on careful histological study a calyx-pyelitis. The satisfaction, however, derived from finding a small carcinoma around a papilla in a kidney removed upon suspicion of being the seat of a neoplasm partially compensates for the regrets.

Tumors of Renal Pelvis.—The most characteristic tumor involving the renal pelvis is the papillary carcinoma which corresponds in its histological architecture to the papillary carcinoma of the bladder. It may grow into the renal parenchyma and be mistaken for a primary renal tumor. A tumor of this type found within the renal parenchyma is *prima facie* evidence that it had originated within the pelvic mucosa.

Occasionally one finds a prickle-cell carcinoma within the renal pelvis usually associated with presence of a calculus, or some other form of irritant.

Lipomata, lymphangiomata and fibrosarcomata are of rare occurrence within the kidney pelvis. The lipoma may be benign or malignant (liposarcoma), the latter giving rise to distant metastases. The metastatic deposits are identical in structure to the sarcomatous component of the parent growth; but in addition may show the presence of fat cells which are carried along with the malignant cells in their migration from the parent tumor.

Hæmaturia is the initial symptom in the vast majority of cases. Secondary hydro- or hemato-nephrosis is of frequent occurrence in pelvic tumors as a result of their tendency to obstruct the ureteropelvic juncture. According to Mock (*J. d'Urol.*, vol. iii, p. 5, 1913), two-thirds of the primary pelvic tumors give rise to this complication. Unilateral hæmaturia established by cystoscopy accompanied by a filling defect involving the renal pelvis only suffices to make the diagnosis of pelvic tumor suspicious. In the presence of a hydronephrosis the diagnosis becomes more certain.

STATISTICAL ANALYSIS OF PRESENT SERIES

TABLE I

Symptoms	Number of Cases	Percentage
Hæmaturia	21	84
Loss of weight	14	56
Renal pain	17	68
Tumor	14	56
Varicocele	3	12
Males	17	68
Females	8	32

JOSEPH A. LAZARUS

SUMMARY.—Malignant tumors of the kidney occurred three times more frequently in men than in women. The outstanding symptom is hæmaturia, which occurred in 84 per cent. of the patients. In slightly more than one-half of the patients there was a history of loss of weight, and in 56 per cent. of them a tumor was noticed. Seventeen, or 68 per cent., complained of pain in the affected kidney.

TABLE II

Duration of Symptoms	Number of Cases	Percentage
Prior to Operation		
1 month or less	3	68
1 to 6 months	11	
6 to 12 months	3	
1 to 2 years	0	0
Over 2 years	6	24
Duration unknown	2	8

SUMMARY.—Seventeen patients (68 per cent.) have had their symptoms one year or less prior to operation or examination, and of this number eleven (44 per cent.) showed symptoms over one month, and three, or 12 per cent., had symptoms over six months. Six patients (24 per cent.) presented their initial symptoms two years or longer before the diagnosis was made.

TABLE III

Positive Diagnostic Signs	Number of Cases	Percentage
Tumor	14	56
Deformity in pyelogram	24	96
Reduced 'phthalein concentration	3	12
Blood from ureter catheter	12	48
Varicocele	3	12
Metastases before operation	3	12

SUMMARY.—The outstanding diagnostic sign of renal tumor is a deformity in the pyelogram seen in 96 per cent. of the cases, while the presence of a palpable tumor was ascertained in 56 per cent. The presence of bleeding, as determined by the passage of a ureter catheter, occurred in 48 per cent. An interesting feature of this chart is the fact that only three patients showed reduced 'phthalein concentration from the affected kidney.

TABLE IV

Age Incidence	Number of Cases	Percentage
First decade	0	
Second decade	0	
Third decade	0	
Fourth decade	1	4
Fifth decade	5	20
Sixth decade	9	36
Seventh decade	9	36
Eighth decade	1	4

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SUMMARY.—The largest number of cases seen in this group occurred in the sixth and seventh decades, a combined incidence of 72 per cent.

TABLE V

Treatment and Side Involved	Number of Cases	Percentage
Nephrectomy	19	76
Inoperable	2	8
Refused operation	4	16
Post-operative X-ray treatment	14	56
Right kidney	13	52
Left kidney	12	48

SUMMARY.—The right kidney was practically as frequently involved as the left (13 to 12). Only two patients of this series were considered inoperable because of the presence of hopeless metastases. Of the nineteen patients operated upon, fourteen were subjected to deep Röntgen therapy after operation. It is the writer's belief that post-operative X-ray therapy is of positive value in controlling metastases.

TABLE VI

Metastases and Complications	Number of Cases	Percentage
Metastases in lungs	11	44
Metastases in liver	5	20
Metastases in bones	2	8
Metastases in scar	3	12
Subphrenic-space infection	1	4

SUMMARY.—Most of the metastases occurred in the lungs, 44 per cent.; while the liver was invaded in five patients, an incidence of 20 per cent.

TABLE VII

Histological Study of Renal Tumors	Number of Cases	Percentage
Hypernephroma of kidney	14	73.7
Adeno-carcinoma of kidney	3	15.8
Adeno-carcinoma of pelvis	1	5.3
Squamous-cell carcinoma of pelvis	1	5.3

SUMMARY.—The vast majority of tumors were hypernephromas, 73.7 per cent.; while 15.8 per cent. showed adeno-carcinoma of the kidney. In only two cases were the tumors primary in the renal pelvis.

TABLE VIII

End-results—Based on 21 Patients Traced	Number of Cases	Percentage
Lived 1 month or less	3	42.9
Lived 1 to 6 months	4	
Lived 6 to 12 months	2	
Lived 12 to 18 months	3	14.3
Lived 18 to 24 months	2	9.5
Lived 2 to 3 years	4	19.
Lived over 3 years	2	9.5
Recently operated on	1	4.8

SUMMARY.—This chart indicated that 57.2 per cent. of the patients of this series were dead within eighteen months after the recognition of the disease or after operation; while 28.5 per cent. of the patients lived two years or more following treatment. The three patients who died within one month were all old men who apparently died of pulmonary emboli. Eight of the twenty-one patients (38.1 per cent.) are still alive, one having passed the six-and-one-half-year limit.

CONCLUSIONS.—A careful analysis of twenty-five patients with malignant tumors of the kidneys reveals many interesting facts. From a symptomatological standpoint, the outstanding symptom was hæmaturia, which occurred in 84 per cent. of the patients. Next in order of importance were pain in the affected kidney, which occurred in 68 per cent., and the presence of tumor in 56 per cent. Three of the eighteen male patients showed the presence of a varicocele, an incidence of 12 per cent. The incidence of males to females was 3 to 1. The greatest incidence occurred in the sixth and seventh decades (72 per cent.).

A review of Table II shows the interesting and startling fact that at least 24 per cent. of the patients presented symptoms two years or more prior to the institution of the first urological study.

A urological survey conducted upon these twenty-five patients brings to light a few outstanding diagnostic signs. In 96 per cent. of these patients a characteristic deformity was noted on the pyelogram. A well-defined tumefaction of the kidney could be felt in 56 per cent. of the cases, while bleeding through the ureter catheter introduced into the affected kidney was noted in 48 per cent. of the patients. It is of interest to note that although all of the kidneys removed showed far-advanced tumors, the 'phthalein concentration was reduced in only 12 per cent. of the cases.

Nephrectomy was performed upon 76 per cent. of the patients examined; two cases were inoperable as a result of the presence of lung metastases, while four refused operative relief. The right kidney was involved in thirteen cases (52 per cent.) and the left in twelve cases (48 per cent.). Fourteen patients were subjected to post-operative deep Röntgen therapy.

Malignant renal tumors metastasize most frequently in the lungs (44 per cent.); while the liver is involved in 20 per cent. of the cases. Skeletal metastases occurred in 8 per cent. of the patients. Recurrence of the tumor in the scar occurred in three patients, an incidence of 12 per cent.

Hypernephroma is the commonest tumor of the kidney, occurring in 73.7 per cent. of this series. Adeno-carcinoma occurred in three patients (15.8 per cent.). Tumors of the renal pelvis were noted in two patients (10.5 per cent.), one being adeno-carcinoma and the other squamous-cell carcinoma.

A review of the end-results in this group of cases indicates that 57.2 per cent. of the patients died within eighteen months after the recognition of the disease, or after the institution of treatment; while 28.5 per cent. lived two

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years or more after operation. Included in the group of patients who died within the eighteen-month period, there were three old men (14.3 per cent.) who died of pulmonary embolus. Deducting this number which might be considered as surgical accidents from the group of twelve, we find that 42.9 per cent. of the patients actually succumbed from causes directly attributable to the renal tumors within the eighteen-month period. Eight patients (38.1 per cent.) of the twenty-one who were traced are still alive, one having passed the six-and-one-half-year limit.

That surgical intervention has a decided place in the treatment of even advanced cases of malignant tumors of the kidney, since most of the cases of this series really were advanced, is attested to by the fact that 28.5 per cent. of the patients included in this series lived two years or more after the institution of treatment. Yet, the fact that 57.2 per cent. of the patients are dead within eighteen months after operation suffices to indicate that there is something radically wrong in our method of handling such patients. It is the opinion of the writer that one of the chief causes accountable for the poor results following treatment is the failure to recognize the incipient symptoms of this dreadful disease early enough to give the patient the benefit of surgery at a time when it would do him the most good. Could the public and the general practitioner be made to realize the importance of hæmaturia as indicating a serious ailment of the genito-urinary tract, it is certain that a great step forward would be made in the early recognition of renal tumors. It is also the belief of the writer that urological surgeons could by a bolder approach broaden the field of operability in this group of cases, even going so far as to open the renal vein for the purpose of removing a neoplastic thrombus. A carefully planned course of deep Röntgen therapy following extirpation of the diseased kidney carried out over a long period has been found a great aid toward the control of metastases. The early recognition of renal tumors coupled with radical extirpation must lead to a more hopeful prognosis.

CONGENITAL ABSENCE OF TESTES (ANORCHIA)*

By VIRGIL S. COUNSELLER, M.D. AND MAURICE A. WALKER, M.D.
OF ROCHESTER, MINN.

FROM THE DIVISION OF SURGERY OF THE MAYO CLINIC

FEW reports have been made concerning the absence of testes. In the last two decades such instances have been reviewed in Dutch and German literature, but not in English, so far as we have been able to discover. We believe, therefore, that in addition to a description of the two cases we have observed, a review of nine previously reported is justifiable.

CASES REPORTED FROM THE LITERATURE OBSERVED AT NECROPSY

CASE I.—Cabrol, in 1564, performed necropsy on a man hung for rape. He was unable to find any testes.

CASE II.—An anonymous author in 1732, in dissecting the body of a youth who had been found dead on the street, found complete absence of testes. (Cited by Koopman and by Wildbolz.)

CASE III.—Kretschmar, in 1801, dissected the body of a child who had lived eight days. The scrotum was empty, and there was complete anal atresia; the child had passed meconium and feces in the urine. The testes, spermatic cords, and seminal vesicles were absent. An abnormal opening through the prostate gland connected the rectum and urethra.

CASE IV.—The first American case was described by Fisher in 1839. A man, aged forty-five years, had died of pneumonia. Immediately after birth, the diagnosis of "natural castrate" had been made. He had never had sexual desire. Necropsy revealed a somewhat feminine habitus, with little facial or pubic hair. The penis was the size of that of a ten-year-old boy. The scrotum was small and did not contain testes; the tunica dartos, tunica vaginalis communis, and cremaster muscles were normal on both sides. The vas deferens ended on the left side in a small nodule thought to be the epididymis; on the right side, the vas ended in a small, sac-like dilatation. The spermatic arteries and veins were so small they were found with difficulty.

CASE V.—Frieze, in 1841, examined a full-term fœtus at necropsy. External genitalia were absent, and there was no trace of testes, epididymis, spermatic cords, seminal vesicles, or prostate gland.

CASE VI.—Le Gendre and Bastien, in 1849, found at necropsy of a full-term fœtus, a small scrotum. The inguinal rings were closed, and a spermatic cord was present on each side, starting at the external opening and ending blindly in the scrotum. Vasa deferentia, seminal vesicles, and other organs were normal. No trace of testes or epididymis was found in the body.

CASE VII.—Godard, in 1860, performed necropsy on a man, aged sixty-one years, whose voice and habitus had always been of feminine type. He had never had intercourse; he had no axillary or pubic hair, or beard. The penis was thirty-five millimetres long. There was no scrotum, and the inguinal canals were empty. No trace of testes or epididymis could be found. The vasa deferentia ran from the prostate gland around the urinary bladder, ending blindly in the peritoneum behind both inguinal regions. The spermatic vesicles were present.

* Submitted for publication May 12, 1932.

CONGENITAL ABSENCE OF TESTES

CASES FROM THE LITERATURE OBSERVED AT SURGICAL EXPLORATION

CASE VIII.—Wildbolz, in 1917, reported the case of a man, aged twenty years, without testes. He had never had mumps or any other infectious disease. A change of voice had not occurred; he had never had erection, libido, or seminal emissions. A physician was consulted because of a drawing sensation in the groin. He had a feminine habitus, and no facial, axillary or pubic hair. The prostate gland and seminal vesicles were not palpable; the penis was only four centimetres long. The scrotum was very small; testes were not palpable in it or in the groin; hernias were not present. Under anaesthesia, bilateral inguinal incisions were made and both inguinal canals were widely opened. A small but complete left spermatic cord reached well into the scrotum. The vas deferens was 2.5 millimetres in diameter, ending in a small rounded mass of connective tissue, ten by eight by four millimetres. A similarly well-developed spermatic cord was found in the right inguinal canal, ending at the neck of the scrotum, but without any swelling at the peripheral end of the vas deferens. The abdominal cavity in the region of both internal inguinal rings was thoroughly palpated but a structure could not be found that in any way resembled a testis. Microscopically, the nodule at the end of the left vas deferens was found to be mostly fibrous tissue containing a few atrophic tubules, perhaps the remains of an epididymis.

CASE IX.—Koopman, in 1930, reviewed the subject of congenital anorchia, and added one case proved by operation. Twins, aged thirteen years, were brought to him in 1922; both were feeble-minded, and each had a small penis, a small empty scrotum, without testes palpable in the inguinal canals. Shortly afterward, one of the boys was operated on for acute appendicitis. No trace of a testis could be found in the inguinal canal or in the abdomen. The spermatic cord was present on both sides, but with small vessels, ending in the skin of the scrotum. The prostate gland was present, but the seminal vesicles were absent.

CASES OBSERVED IN THE MAYO CLINIC

CASE X.—A boy, aged fourteen years, was brought to the clinic in August, 1931, because the testes had never descended into the scrotum. His father had died of carcinoma of the bladder. The boy had had mumps, chicken-pox, diphtheria, and scarlet fever. Hernias had not been noticed, but he had recently complained of occasional pains in the inguinal regions. For about ten years, the boy had been given various proprietary pills to "force the testes down." His general health was excellent.

The patient was well developed and well nourished, was sixty-two inches tall, and weighed ninety-six pounds. The blood-pressure in millimetres of mercury was 128 systolic and 78 diastolic. The penis was infantile, the scrotum poorly developed, and the symphysis pubis was covered by a large pad of fat. Laboratory examinations of the urine and blood, including complement fixation, gave negative results. The von Pirquet test was negative; stereoscopic roentgenograms of the thorax were negative.

The right inguinal canal was opened and explored. An external inguinal ring was not present. In the inguinal canal was found what appeared to be the vas deferens, extending throughout the length of the canal, and terminating as an atrophic cord as it neared the pubis. The entire right lower abdominal region was explored, but no testis or vestige thereof was found. The inguinal incision was closed. Through a left inguinal incision, the left lower part of the abdomen was explored, with similar results except that a structure resembling the vas deferens was not found.

CASE XI.—A boy, aged eleven years, was brought to the clinic by his parents in August, 1931, because neither testis had been palpable in the scrotum. Three children were living and in good health; another had been born dead. The parents and their immediate ancestors were without inheritable disease or deformity, so far as could be ascertained. The boy's birth had been normal, and he had always been well except for measles, whooping cough, and influenza.

COUNSELLER AND WALKER

The patient was well nourished, was fifty-nine inches tall, and weighed ninety-two pounds. The blood-pressure was 120 systolic and 65 diastolic. Testes were not palpable in the scrotum or elsewhere. Hernias were not found and, because of the preceding case, it was suspected that testes would not be found at operation. The penis seemed to be normally developed for his age. He coughed, and a few scattered fine râles were heard at the base of each lung; stereoscopic röntgenograms of the thorax were negative. The complement fixation tests for syphilis were positive on specimens of blood taken on two separate occasions, as follows: Kline 2+, Kahn 2+; Kline 1+, Kahn 3+. The patient was sent home for two weeks until his cough ceased, when he returned and operation was performed.

The right inguinal canal was opened under gas anæsthesia. Testis, spermatic cord, or hernial sac were not found in it. When the peritoneum was incised, a small vas deferens could be palpated which ended at about the site of the internal abdominal inguinal ring in a small fatty nodule, apparently a rudimentary epididymis. From this region, the vas deferens could be followed as it ran posteriorly beneath the peritoneum, but no testis was found. The incision was enlarged so that the corresponding region on the left side of the abdomen could be palpated from within. There, similar structures were found; a small vas deferens ending in a rounded fatty nodule, but no testis. The right inguinal incision was closed after exploration.

Comment.—Rarity of Anorchia.—Since the testes may lie within the abdomen or in the inguinal canal without being palpable, it cannot be determined definitely by general examination that both testes are actually absent. The true anatomical condition can be accurately ascertained only by surgical exploration or by necropsy. Besides the eleven cases described, other cases have been noted in which the absence of testes was suspected without this anatomical proof. At least ten such cases have been recorded: two were observed at The Mayo Clinic. According to reviews by Gruber and by Meyer, only about twenty-three cases have been described in which one testis was absent, as demonstrated by necropsy or surgical examination. The two cases which we now report were observed at the clinic in the same month.

True Anorchia.—There is a possibility that one or both testes might have been overlooked in some of the cases. The detailed description of observations at necropsy seems to indicate sufficiently accurate and careful search so that testes would have been found if present. Such thorough examination of the patients who were operated on was not possible. However, Scammon has stated that after the third month of fetal life, the testis lies in the iliac fossa. Felix has demonstrated that a testis, if present, will be found in the region of the internal inguinal ring and thus will be easily palpable. Undescended or ectopic testes do not lie in the region of the kidney, as was previously believed.

Embryonic remains may be found microscopically along the path which the testis would take in its descent. If such remains are found, their presence may be taken as fairly good evidence that the testis was never formed.

Cause.—In our two cases the congenital absence of testes might have been due to pre-natal atrophy resulting from intra-uterine disease or trauma, or partial or total failure of embryonic development of the sex glands.

Our first patient had had mumps; the second patient had a weakly positive

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complement fixation test for syphilis. Although either of these diseases might have caused inflammation of the testes, neither patient had ever had symptoms of scrotal, inguinal, or abdominal inflammation, so far as we could learn. Furthermore, it is almost inconceivable that any disease process could occur, either before or after birth, which would not leave some remnant of tissue which could be identified. Bagg, even after causing extensive hematomas of the testis in mice embryos by exposure *in utero* to Röntgen-rays, has always been able to find remnants of degenerated testicular tissue. On the other hand, Wangenstein, 108 days after ligating the internal spermatic artery and veins of dogs, found the parenchymal and interstitial tissues of the testis completely replaced by fibrous connective tissue, but he mentioned that in at least one animal the epididymis was normal. Wangenstein also found fibrous connective tissue completely replacing the testis of a youth, aged nineteen years, six years after all vessels except those accompanying the vas deferens had been divided in the performance of orchidopexy.

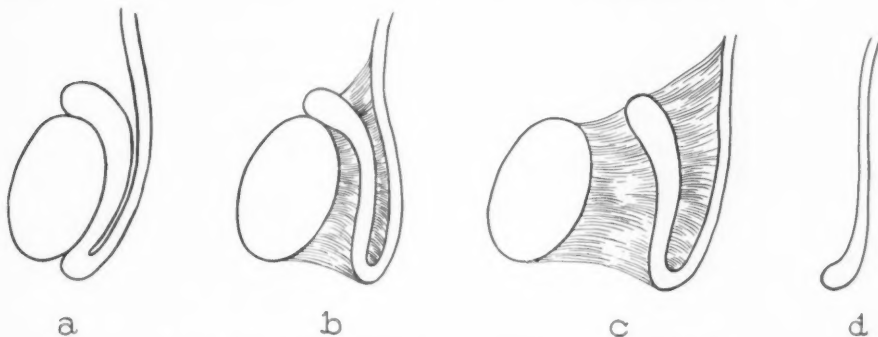


FIG. 1.—Degrees of separation, as occurring in cryptorchidism.

In the cases of anorchia in which the vasa deferentia terminated in small nodules of tissue (Cases IV, VIII and XI), these nodules were reported by the observers to resemble epididymal rather than testicular structures, although this opinion was based on histological study only in Case VIII. The presence of vasa deferentia leading in the direction of the inguinal canals (Cases IV, VI, VII, VIII, IX, X and XI) might suggest normal embryonic development followed by disappearance of the testes, perhaps by interference with the blood supply comparable to that of Wangenstein's experiments. The spermatic vessels, however, were present in four of these cases (Cases IV, VI, VIII and IX).

Pólya, in 1902, described an embryonic variation at the site of attachment of the epididymis to the testis as occurring in cryptorchids, with three degrees of separation. (Fig. 1, *a*, *b* and *c*.) The frequency of different degrees of separation of the epididymis from the testis in the mesorchium has been confirmed by Eccles, Moschowitz, Frattin, Zipper and Wangenstein. Perhaps the cases of anorchia represent a fourth and final degree of separation, with resulting atrophy and disappearance of the testis. (Fig. 1, *d*.) The belief that anorchia is a developmental defect, not caused by pre-natal disease, is

strengthened by its association with congenital absence of the external genitalia (Case V), and with anal atresia and recto-urethral fistula (Case III); the latter is a relatively common abnormality.

Hernia and Anorchia.—When the matter of hernia was mentioned at all (Cases VI, VIII, IX, X and XI), it was stated definitely that hernia was not present. Eccles found that more than half of all patients with cryptorchidism had an associated inguinal hernia. Therefore, if hernia is absent and the testes are not palpable, it should be remembered that, although the testes are probably only undescended, they may be completely absent. This is of clinical significance, and should be mentioned to such patients or their relatives before orchidopexy is attempted, thus avoiding considerable explanation if testes should not be found.

Effect of Congenital Anorchia on the Development of Secondary Sexual Characteristics.—Three of the subjects described were infants (Cases III, V and VI), and three others (Cases IX, X and XI) were too young to draw any conclusions in regard to the effect of the lack of testes on the development of the secondary sexual characteristics. The first patient described was hung for rape, but no further information is available. Details of the second case were not given. Three subjects (Cases IV, VII and VIII) had definite failure of development of beard and change of voice, lacked libido, and had a feminine habitus. It has been known for centuries that these secondary sexual characteristics fail to develop when the testes have been removed before puberty. Hirschfeld has described the appearance of some of these characteristics subsequent to removal of sex glands after puberty. In cryptorchidism, on the other hand, although spermatogenesis is practically always absent, the secondary sexual characteristics usually develop normally. If a boy does not have palpable testes, however, no attempt should be made to distinguish cryptorchidism from anorchia. If the testes are not in the scrotum, Wangenstein and others have emphasized that the optimal time for placing them there surgically is between the ninth and eleventh years, after any possibility of delayed spontaneous descent has passed, and before puberty, which should normally be associated with spermatogenesis and the advent of the secondary sexual characteristics.

Summary.—Eleven cases of congenital absence of both testes have been described, including two of our own. The possible causes of anorchia have been considered, but no definite conclusion has been reached. The only constantly associated physical finding, in addition to inability to palpate the testes, is absence of a congenital inguinal hernia, but this is also frequently absent in simple cryptorchidism.

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EXTRAVESICAL URETERAL OPENING CAUSING URINARY INCONTINENCE

By THOMAS N. HEPBURN, M.D.

OF HARTFORD, CONN.

URINARY incontinence caused by an extravesimal ureteral opening is a great misfortune to its unhappy possessor, but if diagnosed, it can be easily cured by surgery. Its rarity makes it a most intriguing example of congenital pathology. Therefore, I am reporting the following case, analyzing the previously reported cases, reviewing the embryology, and drawing conclusions based on this study.



FIG. 1.—An X-ray with a catheter up the right ureter and skiodan injected up both ureters. Note the club-shaped renal pelvis of left kidney and the ureteral shadow running out under the pubic arch.

Mrs. H. S., age twenty-five, married, U. S., was admitted to the Hartford Hospital September 29, 1932, with a history of urinary incontinence.

Both parents were deaf and dumb. Her past history shows a very healthy life with the exception of the disabilities connected with her urinary incontinence. Married four years—three living children, the youngest three weeks old.

The present illness dates as far back as she can remember. She has had to wear a pad all the time, but she voids normally as well. She is a pretty, well-built, vivacious young woman—very fond of dancing, and volunteered the observation that she could keep dry as long as she danced. When she sat down after dancing she would immediately wet herself. In order to cure this difficulty she has had her bladder explored, without benefit, when she was sixteen at a large New England Hospital, and when nineteen had been under observation for two weeks at another excellent diagnostic centre where she was cystoscoped by urologists. The cause of her disability was not discovered. Feeling that she had consulted the highest authorities, she had given up all hope of relief. She entered the Hartford Hospital to be delivered of her third child. She was brought to the

attention to the Urological Department after her delivery.

Local examination revealed a supernumerary ureteral opening in the vestibule in the midline just below the external urethral opening. I could not catheterize this opening because of its minuteness but I did succeed in injecting skiodan through a small hypodermic needle. The picture is seen in Fig. 1. It will be noted that this patient has

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a normal right kidney. I searched for a normal left ureteral opening in this woman's bladder on two occasions, but failed to find it. My pre-operative diagnosis was that this woman had a normal right kidney, and a double left kidney. Neither of the left kidneys was functioning, and the top kidney was of the rudimentary type and had an ectopic ureter opening in the vestibule. I advised left nephrectomy because I could get no evidence of a functioning lower left kidney. This advice was accepted. The operation was exceedingly simple, the kidney was hardly larger than a large lymph-gland. (Fig. 2.) It was a double kidney—each kidney being of the rudimentary type.

Report on pathological specimen by Dr. Ralph E. Kendall of the Pathological Department of the Hartford Hospital: Congenital anomaly of kidney. Double kidney. Double ureter. The specimen consists of a kidney, 6 by 3 by 2 centimetres, with double ureter attached. The surface is lobulated. The capsule is slightly thickened and adherent in focal areas. On section the upper pelvis is divided into three rudimentary calyces. There is a slight relative dilatation and its capacity is estimated to be at 2 cubic centimetres. Renal parenchyma averages 1.5 centimetre in thickness. A narrow, but well-defined, cortical structure can be seen. There is a sharp, fibrous



FIG. 2.—Double kidney after removal. Note the undeveloped form. The ectopical ureter going to the upper kidney.

margin separating the renal parenchyma of the upper and lower portions. The inferior pelvis is somewhat smaller and likewise is divided into three rudimentary calyces. It is estimated to have less than 1 cubic centimetre volume. The brownish parenchymal tissue averages 5 millimetres in thickness and no cortical markings can be identified in the gross. The upper ureter is 7 centimetre in length and 5 millimetres in diameter. The lower is 5 centimetres in length and 4 millimetres in diameter. Each contains a well-defined lumen and smooth mucous membrane.

Section of the upper pole of the kidney shows a parenchyma that is essentially normal in character. The glomeruli are intact. The convoluted tubules show a normal cuboidal type of epithelial lining. A few of the tubules are slightly dilated and some contain an amorphous pink-staining material. There is no inflammatory involvement and no definite fibrosis. There is a sharp, fibrous tissue capsule separating the upper and lower portions of the kidney. In the lower pole there is an extensive diffuse fibrosis through the parenchyma separating and distorting the tubules. Many of the tubules are atrophic; others are slightly dilated with an atrophic lining epithelium. Glomerular tufts are very few, only one-half dozen being found in several sections. These are atrophic and fibrotic. Both ureters and pelvis have a normal micro-

scopical structure. The epithelial lining is characteristic and a smooth muscle coat, though somewhat atrophic, is complete. No inflammatory reaction is seen.

Analysis of Previously Reported Cases.—This congenital error has been reported 103 times—thirty-nine at autopsy; sixty-four in the living. Thirty-three cases were in males and seventy cases were in females. Of the cases found in males thirty-one were found at autopsy. Only two were recognized in the living—Day's and Chute's cases.

The Locations of the Extravesical Opening in the Male Cases Were: In prostatic urethra, twenty-four cases; in prostate, two cases; in seminal vesicle, five cases; in ejaculatory duct, two cases. The reason why it is discovered in males largely at autopsy is because the fluid from the extravesical opening finds its way into the prostatic urethra and is forced back into the bladder by the strong external sphincter, so that there is no incontinence. Of the seventy cases in females, nine were found at autopsy.

The Locations of the Extravesical Opening in the Female Cases were: In the vestibule near urethral meatus, fifty-three cases; in the urethra, twelve cases; openings not found, five cases.

Type of Kidney Having Extravesical Ureteral Opening.—Wherever the renal end of an extravesical supernumerary ureter has been described—either by pyelogram, or at renal exploration, or at autopsy—it has been described as ending in a rudimentary kidney or pus sac with rudimentary renal cortex. Wherever the renal end of an extravesical ureter leading to a single kidney has been described, we find that three led to fused kidneys—one led to a sac; one was atrophic. In the other cases no description of the kidneys is given.

Embryology.—The embryological development of these extravesical ureter openings gives an explanation for their occurrence and a suggestion as to their treatment. Text-books in embryology (Keibel and Mall; Prentiss and Arey) show the transition of the mesonephric system and cloaca into the metanephric system, bladder, genitals and rectum. The cells on the posterior lateral wall of the Wolffian or general excretory duct have the potentiality in one area of growing into the ureter and pelvis and calyces. A little farther down on the Wolffian duct are the cells which develop into the genital tract. The ureter starts normally from the general excretory duct as a little bud which protrudes upward and backward. On the tip of this bud are the cells which develop into the calyces and collecting tubules. Should this ureteral bud start lower down on the Wolffian duct in the genital area, its opening would then be not in the bladder, but into some of the genital organs. If female, it might open into the urethra or vestibule. While many accounts use the name vagina as place of ureteral opening, I find no case actually opening into the vagina—*i.e.*, between the hymen and the uterus. This is what one would expect as embryologically the female sex organs develop from the Müllerian ducts and not from the Wolffian ducts. If male, it might open into the seminal vesicle, prostate, ejaculatory duct, or urethra.

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Supernumerary Ureters and Kidneys.—Seventy-eight of the cases report that the extravesimal openings were from supernumerary ureters leading to supernumerary kidneys. (See diagram 1.) Twenty-five of the cases were reported as openings from single kidneys, but in view of the fact that it is very easy to overlook a ureteral opening clinically, it is evident that only those cases reported as verified by surgical exploration of the renal region or at autopsy, or by pyelograms should be credited. Only eight of these twenty-five cases were verified—this leaves seventeen cases unverified. Doubtless many of these were cases of supernumerary ureters. Therefore it may be stated that this congenital anomaly is noted as associated with supernumerary ureters and kidneys in 90 per cent. of the cases reported.

Non-supernumerary Extravesical Ureteral Openings.—Eight cases were found at autopsy, of which three cases were from fused or horse-shoe kidneys. (See diagram 2.)

Multiple Extravesical Ureteral Openings.—Seven of the 103 cases were reported as having two extravesimal ureteral openings. Two cases were bilateral single ureters. Both infants and autopsy findings—one described as having no bladder (which seems to me to be embryologically improbable). (See diagram 3.)

Two cases were where both ureters from a double kidney on one side opened extravasically. (See diagram 4.)

Three cases were where there was bilateral duplication, and the ureter leading to the upper kidney on each side opened extravasically. (See diagram 5.)



DIAGRAM 1



DIAGRAM 2



DIAGRAM 3



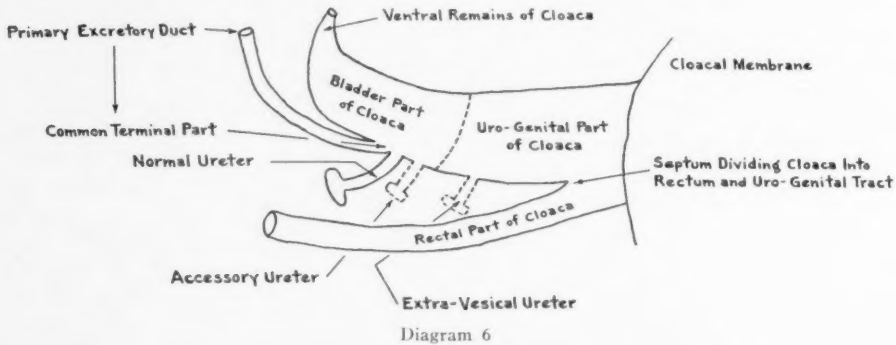
DIAGRAM 4



DIAGRAM 5

Instead of there being only one ureteral bud, there may be two ureteral buds—one placed above the other as shown in diagram 6, the lower bud always ending in a renal structure higher than the upper bud. These two ureteral openings may both be so close to the normal position that they open into the bladder, or they may both be so low down on the Wolffian duct that they open into the urethra or genital tract outside of the bladder, or the upper one may open as normally into the bladder, and the lower one may open so low down that it empties into some part of the urethra or genital tract.

From the report of the clinical cases I find that none of these ureters opening extravasically have normal kidney structures, but end in a primitive pelvis with a primitive nephrogenic cap. Therefore, it would appear that when the ureteral bud starts so low down on the Wolffian duct that its opening is extravasical, then it carries on its tip no cells with the potentiality of developing into multiple calyces and the collecting tubules of the medulla, or of stimulating the nephrogenic cap out of its primitive character to develop



into a normal cortex. At least, where the renal pelvis remains primitive then the nephrogenic cap remains primitive. Of course this is found also at times when the ureter opens into the bladder, or with cleft ureters, but with ureters opening extravasically it is found in 98 per cent. of the cases.

Diagnosis.—The diagnosis of this condition can and should be made from the history alone. It is seen clinically in females 98 per cent. of the time. The history is practically the same in all the reported cases. The woman has been wet ever since she can remember, so that she always had to wear a pad. Otherwise the urinary history is perfectly normal. The patient has to void regularly as does any normal woman. There may be additional symptoms, such as pain in the back, due to hydro-ureters secondary to the strictured outlet, but only rarely is that a prominent feature of the history. This history of being wet since infancy, yet with an otherwise normal urination should make one very suspicious of an extravasical ureteral opening.

The local examination, however, will be disappointing because it is almost impossible to see the tiny opening. The drop of urine appears as

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if it were by magic. I would advise anyone to inject intravenously indigo-carmin before looking for the opening. This may give the urine a faintly blue tinge. When found one will not be able to pass a catheter more than a few centimetres, for it will coil up in the dilated ureter behind the bladder, or the opening may be so small that it admits no catheter. However, one can usually show it graphically by the injection of some shadowgraph fluid—preferably skiodan. This will show a somewhat tortuous ureter running to the upper pole of a double kidney. This ureter will end in a club-shaped primitive pelvis with no calyces, or only the primary ones typical of the rudimentary kidney. The lower end of the ureter has a tendency to be dilated secondary to the obstruction of the small opening in the vestibule. Practically all of these obstructed cases with hydro-ureters show chronic infection.

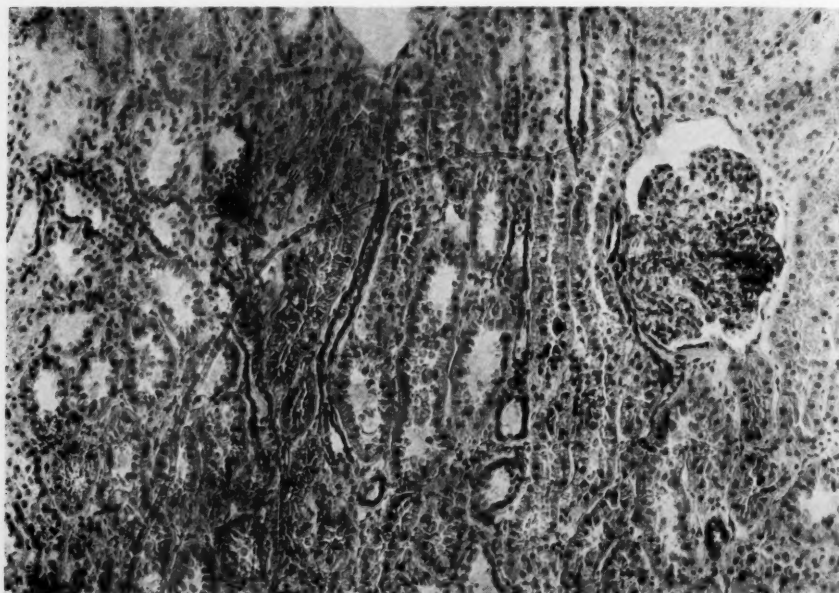
Function.—As one would expect, the function of these supernumerary rudimentary kidneys with the ectopic opening into the vestibule is always very poor. In fact the excretion of dye is so poor that one can get only the slightest discoloration of the fluid which comes from these ureters after intravenous injection of indigo-carmin. However, they can excrete water enough to keep one wet or to form dilated ureters or pelves in case the ureteral opening is too small.

It is a fascinating speculation as to what is necessary to stimulate the nephrogenic cells of the cap to develop into a normal renal cortex. Or what is necessary in the ureteral bud to make it develop into a normal pelvis with multiple calyces and tubules. I have examined many rudimentary kidneys and have never seen a normally developed cortex where the pelvis and calyces were rudimentary. Once I have seen a rudimentary cortex where the pelvis and calyces were normally developed. Therefore, one can say that a normal pelvis and calyces may develop without the stimulation of a normally developing renal cortex. Further one may say that whatever stimulating interaction there may be between these two structures to make each develop normally, the anlage for this potentiality seems not to be present in ureteral buds which have their origin from that part of the Wolffian body which develops into the genital organs or urethra of the male, or that develops into the urethra or vestibule of the female.

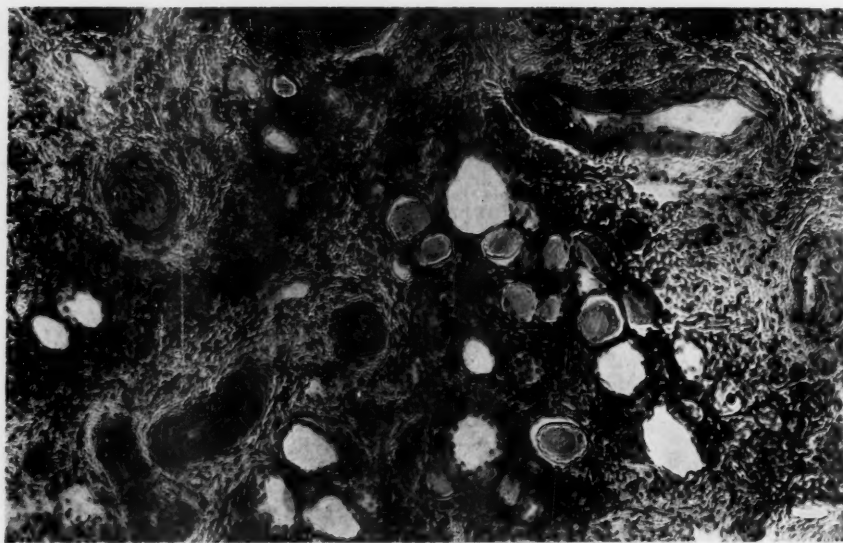
Embryologically there is no reason to expect that the ureter can ever open into the vagina, uterus or tubes, and no clinical case has been reported in which such an opening has existed, although many have used the term vagina when they meant vestibule. This may be predicated from the fact that the female genital tract above the hymen develops entirely from the Müllerian ducts. Note especially Gaertner's ducts which are the embryonic remains of the old mesonephric system.

Spitzer and Wallin in 1928 (*ANNALS OF SURGERY*, vol. lxxxviii) reported a beautiful case of bilateral supernumerary extravesical ureters, and were evidently very much interested as to whether these supernumerary extravesical ureteral openings led to true ureters and true kidneys, or whether

they were remnants of Gaertner's ducts, and they ended their conclusion with the statement that they wished to emphasize "That cases similar to the



A



B

FIG. 3. Microphotographs of renal cortex of this case showing definite mesonephric type of renal tubules. (A) Upper kidney. (B) Lower kidney. The lower kidney shows marked fibrosis.

one we have described are strongly suggestive of persistent embryonic structures"—meaning "Gaertner's canal" or the "persistent remains of the mesonephric or Wolffian duct." Their bilateral ureteropyelogram showed the extravesimal ureters leading to the normal metanephric lumbar location.

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If Spitzer and Wallin's speculation were correct, that is if these extravascular structures are not true ureters, but remnants of the old mesonephric duct or canal of Gaertner, one would expect this tube to lead to the embryonic mesonephric tubules in the region of the paroöphoron near the ovary. In no case has this been true. In each case the ureter has led to a renal structure associated with the metanephric system, and never to the mesonephric system.

Microphotographs of transverse sections of the ureters, and of the renal cortices of my case (Fig. 3) are conclusive evidence that these structures belong to the metanephric system. This case is peculiarly fortunate because the lower kidney drained into the bladder and the upper kidney into

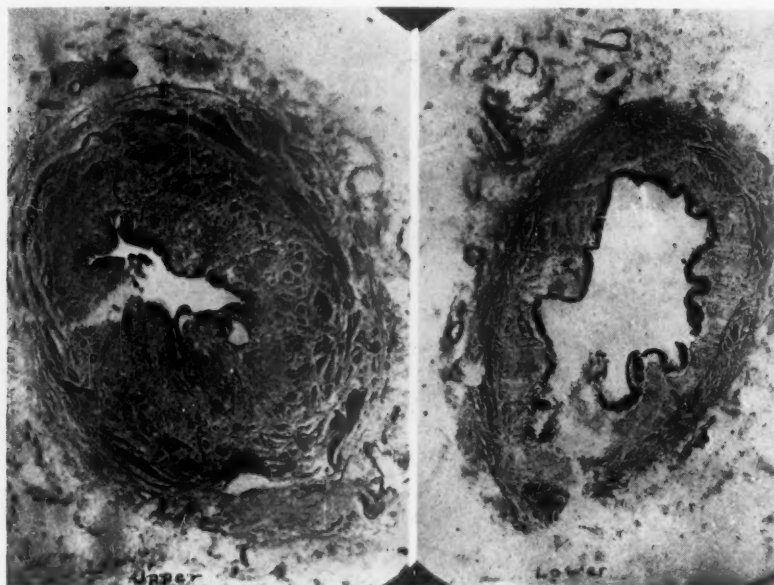


FIG. 4.—Microphotograph of a cross-section of the ureters showing normal metanephric ureteral structure of epithelial and muscle layers, thus differentiating it from the mesonephric duct of Gaertner.

the vestibule. Both kidneys are rudimentary in type, and a study of the photograph shows that the upper kidney had a better cortex than the lower kidney, and is what one would expect to find in rudimentary developed nephrogenic tissue. The ureters show the same type of wall with a definite smooth muscle coat.

Without doubt I think we may concede that these structures are not remnants of Gaertner's duct, but ordinary metanephric structures which have remained rudimentary in form. Although the extravascular ureteral bud may grow into the nephrogenic cellular body and acquire a true nephrogenic cap, they do not have the potentiality to develop into a normal pelvis and calyces or to stimulate its nephrogenic cap into a normal cortex. Therefore, while a ureter opening normally may lead up to a rudimentary form of kidney; a supernumerary extravascular ureter always leads to a rudimentary

form of kidney, and, if not a supernumerary ureter, in the cases reported so far, it leads to either a horse-shoe kidney or rudimentary kidney.

Treatment.—In view of the above analysis, the treatment of this condition is either nephrectomy or resection of the supernumerary, rudimentary kidney. Any surgery aimed at preserving this kidney is unjustified. Ligation of the ureters as reported in several cases is entirely too dangerous a procedure because the pelvis of these kidneys is always infected.

Conclusion.—(1) A new case with extravescical ureteral opening is reported.

(2) An analysis of the preceding cases is made, which shows that

(A) Ninety-eight per cent. of the clinical cases are found to be in the female, and ninety per cent. of these are associated with supernumerary ureters.

(B) The supernumerary ureter with an extravescical opening always leads to a sac-like pelvis which never divides into more than the primary calyces, and drains a rudimentary renal cortex of very slight functional capacity.

(C) This rudimentary supernumerary kidney is always situated at the upper pole of the normal kidney structure.

(D) That in reporting cases many authors mistake the vestibule for the vagina.

(3) From a study of the embryology and the clinical reports there is no evidence that in the female these extravescical ureteral openings ever open into the tubes, uterus or vagina—these structures being derived from the Müllerian ducts and not from the mesonephric or Wolffian ducts.

(4) Spitzer and Wallin's suggestion that these extravescical supernumerary ureteral structures in the female are remnants of Gaertner's ducts, and that the renal structures that they drain are mesonephric remnants and not rudimentary metanephric cells, cannot be maintained because:

(A) These ureters never lead to the region of the paroöphoron, but to the normal metanephric region.

(B) Because of the microscopical structure of the (1) ureter, and (2) of the renal cortex.

(5) The speculation is indulged in as to why the nephrogenic cap to these supernumerary extravescical ureters never develops beyond the rudimentary stage. It is suggested the lack of the cells in the ureter with the potentiality to develop into calyces and tubules is probably the cause. These cells must have some stimulating element necessary to arouse the nephrogenic cells to develop into a normal cortex.

(6) The treatment of these cases is always surgical and should be nephrectomy or heminephrectomy according to the type of case. There is no excuse for ligations, or implantations or anastomosis of ureters.

INFECTED SUPERNUMERARY URETER AND PELVIS OF KIDNEY; HEMI-NEPHRECTOMY

BY MORTON S. BRODY, M.D.

OF NEW BRUNSWICK, N. J.

FROM THE UROLOGICAL DEPARTMENT OF ST. PETER'S GENERAL HOSPITAL

THE comparative frequency of developmental anomalies of the urinary tract, recognized at first only at autopsy as interesting embryological diversities, and at a later period discovered accidentally during the course of abdominal operations, has become known only since the general adoption of modern methods of urological investigation, more especially of urography, and their relationship to co-existent lesions of the urinary system established, and appropriate measures taken in certain cases for their relief. Braasch¹ has made a complete study of these conditions, and concludes that duplication of ureters is practically always found with double renal pelvis, these latter surrounded by separate or fused kidneys.

The diagnosis of a double ureter is most easily made by cystoscopy and the indigo-carmin test. A ureter fissure is assumed only when the ureteral catheter introduced to various levels reveals in one instance a normal and in another a pathological urinary finding, or when pyelography points to abnormal kidney relations. The symptomatology pointing to a ureter fissure or double ureter may be indefinite. In reference to such a condition is the involuntary discharge of urine in spite of the fact that voluntary emptying of the bladder is possible. In such cases one must not be satisfied with a diagnosis of "incontinence of urine," but look after its cause. In the female, simple inspection of the vulva and of the vagina shows the opening from which fluid escapes in form of drops. If the opening is into the urethra then it can be easily determined, in male as well as in female, by endoscopy. The case presented in the present communication is somewhat similar to the two cases reported by Kilbane² and the one by McClelland³ which showed a supernumerary ureteral orifice opening externally on the lateral margin of the urethral meatus, showed the ureter fissure immediately below the urethral orifice. Both of Kilbane's cases were nephrectomized while McClelland obtained a cure by ligating the aberrant ureter exposed through an abdominal extra-peritoneal approach. Extravesical openings of the ureter have been reported into the prostatic urethra, the seminal vesicals, the vas deferens, the vagina and the anterior urethra.

CASE.—L. W., female, aged twenty-one years, consulted Dr. L. A. M. Feher November 8, 1931, for constant dribbling which she had had since childhood. A sanitary pad which she wore constantly seemed to take care of her condition and it did not in any way interfere with her routine daily work or hinder her from attending social functions. She was now engaged to be married and decided for the first time to consult a physician

to find out the cause of her trouble and have it corrected. She had never had any serious illness and had never been operated upon. The physical examination (Fig. 1) was negative with exception that on vaginal examination a small slit-like opening was seen just below the normal urethral orifice, from which cloudy drops of fluid were exuding. This orifice was probed and catheterized and the fluid obtained sent to the laboratory for examination. A cystoscopic examination was then made and this revealed a normal bladder and double ureteral orifices on the right side of the trigone, one just below the other, from which urine was emitting. After careful inspection of the left side only one orifice could be found. While the cystoscope was still in the bladder the sinus orifice was probed but the point of the probe could not be seen entering the interior of the bladder. The patient then entered the hospital for X-ray study. The sinus orifice was

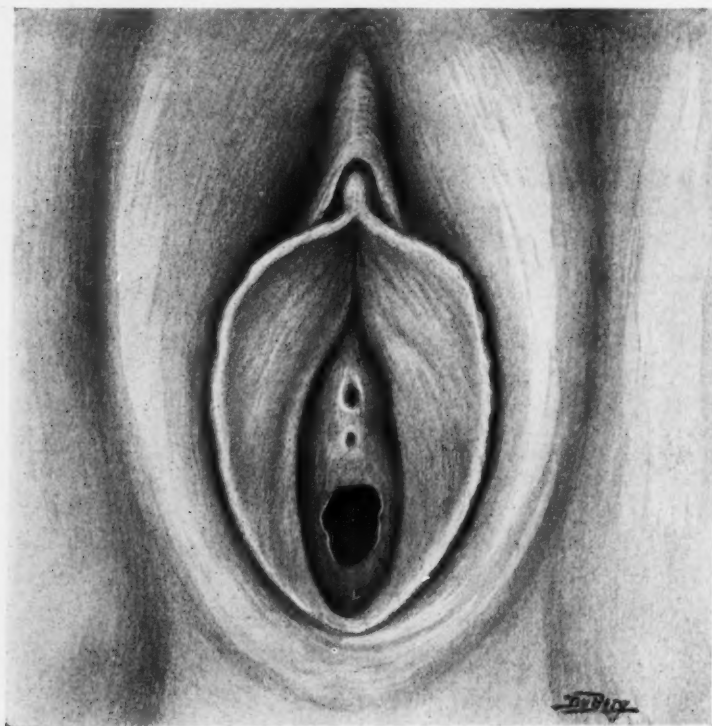


FIG. 1.—Aberrant ureteral opening below the urethral orifice.

then injected with twenty-five cubic centimetres of lipiodol, this amount being considered to be sufficient to fill the sinus tract and an X-ray was taken which revealed only a blind, tortuous sinus. (Figs. 2 and 3.) This procedure was followed with an intravenous injection of skiodan with the hope that the contrasting substance would fill the upper portion of the sinus tract. The X-ray confirmed the presence of a double ureter on the right side but on the left side no definite conclusion could be drawn as the skiodan shadow of the ureter was indistinct. Doctor Feher thought perhaps he was dealing with a tuberculous sinus or an abnormal development of the left ureter. As they were unable to arrive at a definite diagnosis, the patient was again advised to return to the hospital for further study.

Laboratory Report.—The fluid obtained from the sinus contained clumps of pus, epithelial cells, a few blood-cells; the culture was negative for tuberculosis and established the specimen as urine. Blood Wassermann was negative. Blood chemistry: urea, 14.5; sugar, 90, creatinine, 1.3 milligram.

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FIG. 2.—Fissure opening injected with "lipiodol" terminating in a blind sinus tract. Intravenous urogram showing a normal pyelogram of the lower half of the left kidney and a double pelvis and ureter of the right kidney.



FIG. 3.—Retrograde pyelogram of the right kidney showing a double pelvis and ureter with blunting of one of the upper calyces.



Cystoscopic Examination.—November 18, 1931, a cystoscopy was again performed and similar findings were again found as on the previous examination. All three ureteral orifices were then catheterized and no obstruction encountered in any of them. The urine obtained from these openings were reported as normal. Good dye concentration was obtained from all three, but more attention was given to the left ureter, into which seven cubic centimetres of sodium iodide were injected and a pyelogram taken. An opaque catheter was then inserted into the sinus and ninety cubic centimetres of sodium iodide were injected before the patient was conscious of any discomfort. Following this,

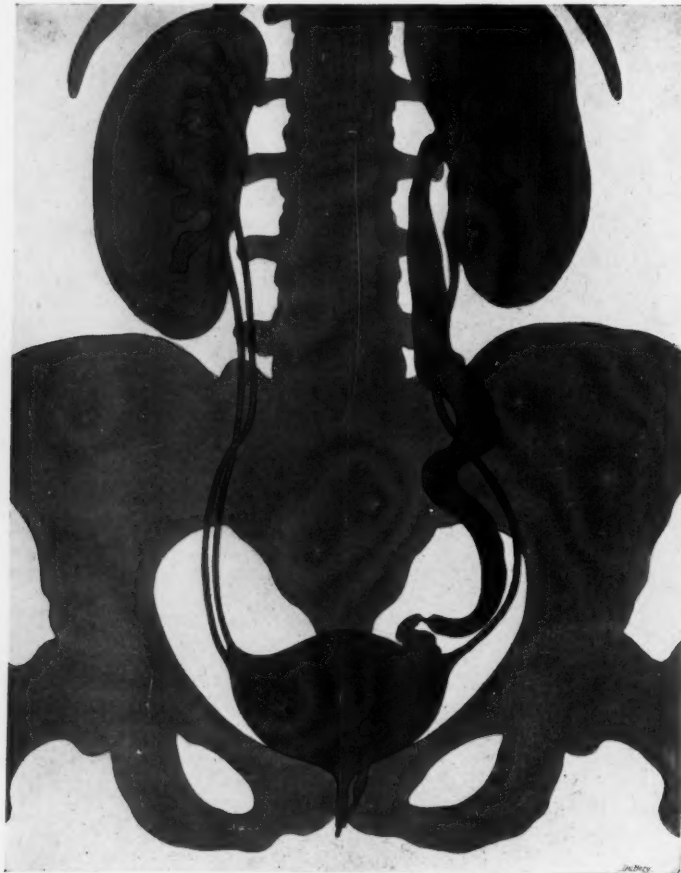


FIG. 4.—A composite picture of the kidneys, pelvis and ureters taken from the intravenous and retrograde pyelograms showing the supernumerary ureter opening just below the normal urethra and ending in a hydronephrotic sack.

another X-ray was taken. Interpretation of these plates was made by the röntgenologist, Dr. William Klein, as follows:

Röntgenological Examination of the genito-urinary tract reveals after the injection of the sinus tract with contrast dye evidence of a supernumerary kidney pelvis on the left side as well as a supernumerary ureter. The upper end of this tract opens into the upper portion of the kidney, at which point it is considerably dilated and at its terminal end reveals what appears to be remnants of minor calyces. This supernumerary ureter runs downward along the vertebral column and is considerably dilated as well as tortuous in its pelvic portion and then is found to open just below the normal urethral

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orifice. (Fig. 4.) The dye injected through the opaque catheter shows a normal ureter and pelvis which opens into the lower portion of the kidney, both major and minor calyces appear normal. On the right side intravenous skiodan and retrograde pyelography reveal a double pelvis, with double ureters running parallel to one another, emptying normally in the urinary bladder. All the major and minor calyces are normal with the exception that one of the minor calyces of the upper pole of the right kidney shows dilatation with blunting.

Diagnosis.—Supernumerary left kidney pelvis as well as supernumerary ureter (dilated) tortuous and atonic with opening (ectopic) just below the normal urethral orifice.

Operation.—After careful study I decided that implantation of the supernumerary ureter into the bladder was inadvisable because of the infection present in the supernumerary kidney. Ligation of the ureter was rejected for the same reason. Exploration of the kidney with the hope of finding a condition that would permit a hemi-nephrectomy was determined upon. December 1, 1931, under gas and ether anaesthesia, the left kidney was exposed through an eight-inch hockey stick incision. The greater part of the kidney was readily separated from the surrounding tissues with the exception of the upper pole, which was firmly adherent. The kidney was finally mobilized, the lower two-thirds was smooth, unsegmented, while the upper pole, the site of an infected hydronephrotic sac, was thickened and diseased. The ureters were then isolated and freed of their connective-tissue adhesions. The ureter opening into the lower part of the kidney appeared normal while the ureter which terminated in the hydronephrotic sac was diseased and dilated to the size of the small intestine. The renal vessels were then isolated and found to divide into two branches before entering the kidney, one branch going to the upper pole, the other to the lower. The upper branch was doubly ligated and divided. The dilated ureter was then divided as far down as possible with a carbolized knife between two chromic transfixion ligatures. It was impossible to remove the entire ureter at this stage and I felt, if necessary, at a future date to do a secondary operation to remove the remaining portion of the diseased ureter. The kidney capsule was then slit along the superior border, around the upper pole and then reflected back anteriorly and posteriorly upon the normal portion of the kidney beyond the line of demarcation which now formed. The upper portion of the kidney was amputated just along the line of demarcation, taking a good wedge of healthy kidney with it. The cut surface of the kidney revealed that a part of the terminal end of one of the calyces had been removed. The edges of this calyx were approximated with a continuous suture, using a fine circumcision needle and gut. The oozing was controlled by four interrupted mattress sutures which dipped deeply into the renal tissue to close the rent. Small pieces of fat were inserted under the suture to prevent cutting through the capsule. The reflected capsule was then sutured over the raw area with a continuous running catgut. A cigarette drain was placed along the sutured pole and the wound closed in layers.

Post-operative Course.—The post-operative course was uneventful, the temperature never rose above 100° F. the first three days and thereafter remained normal. At no time was there any urinary leakage. The cigarette drain was removed on the fifth day and the wound healed by primary union. The urinary dribbling stopped entirely after the fourth day. The patient left the hospital on the twenty-first day in excellent condition. Fig. 4.

Pathological examination of the portion of kidney and ureter demonstrated an infected hydronephrosis with an accessory ureter; ureteritis cystica. Cystoscopy on January 24, 1932, six weeks after operation, revealed a normal bladder, all three orifices functioning normally. Indigo-carmin excreted from the hemi-nephrectomized kidney was four plus in three minutes. A pyelogram was taken of the remaining half kidney, five cubic centimetres of sodium iodide were injected through a catheter but the calyces were not filled to capacity for fear of causing some damage so soon after the operation.

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CONCLUSIONS

- (1) Thorough urological examination necessary for "Incontinence of Urine."
- (2) Pathological changes are frequent in this type of anomaly.
- (3) Resection of double kidney is practical provided the disease is definitely confined.
- (4) Hemi-nephrectomy in a case of an extra-vesical accessory ureter gives good results and the urinary dribbling is eliminated, together with it the somatic and psychic symptoms.

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POST-OPERATIVE URINARY RETENTION *

BY CLAUD G. JORDAN, M.D.

OF PHILADELPHIA, PA.

FROM THE SURGICAL DIVISION B OF THE UNIVERSITY HOSPITAL AND FROM THE DEPARTMENT OF RESEARCH SURGERY,
UNIVERSITY OF PENNSYLVANIA

POST-OPERATIVE retention is that condition in which the patient after an operation finds it impossible to urinate in spite of normal kidney function, a full bladder and the absence of organic obstruction. The time limit beyond which retention after operation must be considered pathological depends on several factors, *i.e.*, the time and amount of the last pre-operative evacuation of the bladder, the duration of the operation, and the fluid intake of the patient. Taking these facts into consideration, we usually are not concerned until eighteen to twenty-four hours after operation. Some writers contend that retention is present as soon as the patient complains of discomfort and inability to void. The majority diagnose retention when palpation and percussion of the bladder show it to be three fingers above the pelvic brim.

In the literature we find the incidence of post-operative retention reported as ranging from 10 to 55 per cent. An analysis of our own series shows an incidence of 12.5 per cent. (eighty-one cases) in 644 operations performed under general anaesthesia. Of the eighty-one cases of retention, thirty-seven or 47 per cent. required catheterization and of these thirty-seven cases, nine or 23 per cent. developed cystitis. One case developed epididymitis. Of the thirty-seven cases requiring catheterization, this had to be repeated in fifteen or 39 per cent.

The series was next analyzed as to incidence of age, sex, type of patient, type of anaesthesia, type of post-operative medication and treatment, and type of operation:

(1) *Incidence As to Age.*—Retention occurred in patients ranging from fourteen to seventy years of age. It was most common in young adults but never occurred before puberty.

(2) *Incidence As to Sex.*—In this series of eighty-one cases, retention occurred in forty-seven females and thirty-four males. These figures confirm the prevalent findings of a slightly higher incidence in women. A few more men than women were operated in this series of 644 cases.

(3) *Incidence As to Type of Patient.*—Of the eighty-one cases of retention thirty-seven were private patients and forty-four ward patients. Considering the much larger proportion of ward patients operated upon we have here a definitely higher incidence of retention in private patients. This finding points very significantly toward the type of patient in which we usually are confronted with this problem. These patients can be spotted almost before operation. They are hypersensitive, apprehensive, psychoneurotic individuals

* Read before the Philadelphia Academy of Surgery, November 7, 1932.

with but little self control. The least pain or discomfort arouses a marked psychic reaction. They are afraid to suffer the pain of urination. When examined the morning after operation these patients will speak to you in a low voice, hesitating even to take a deep breath for fear of pain or rupturing their wound. They have a very low threshold for pain.

(4) *Incidence As to Type of Anæsthesia.*—

TABLE I

Anæsthesia	Cases	Retention	Per Cent.
Ether.....	232	29	12.5
Gas-ether.....	78	21	27.0
Gas.....	206	10	4.8
Spinal.....	124	24	19.3
Local.....	71	0	0.0

Reviewing the above figures one is struck by the high incidence of retention after gas-ether anæsthesia. This might be partially explained by the type of operation for which this anæsthesia is commonly used, that is, in appendicectomies and other lower abdominal operations, but I believe that the addition of ether to the gas carries most of the blame. The depth of anæsthesia has much to do with post-operative retention. The longer and deeper the anæsthesia the higher the incidence of retention. Ether, for this reason, is probably responsible for most cases of retention. A fact which is brought out clearly by the above figures is that a considerable number of spinal anæsthesias are followed by retention, showing that causes other than ether may be responsible for the production of retention. In spinal anæsthesia we probably have a direct interruption of the bladder reflex.

(5) *Incidence of Proctoclysis in Retention.*—Of the eighty-one cases, sixty-three or 77 per cent. received proctoclysis. The eighteen cases which did not receive proctoclysis are as follows:

Hernia.....	5
Cancer of rectum.....	2
Colostomy.....	2
Hæmorrhoids.....	2
Pilonidal cyst.....	2
Appendicitis.....	1
Partial gastrectomy.....	2
Epididymitis.....	1
D. & C.....	1

I believe these data are quite significant with regard to the etiology of retention. Proctoclysis is not always the sole cause of retention, but it is often responsible for it, and retention can be relieved by discontinuing the proctoclysis. With the exception of two gastrectomies and one appendectomy the remainder of the cases which did not receive proctoclysis had operations which either involved the rectum directly or involved the genito-urinary nerves, as in hernia. It is held by Kohler that the sphincter ano and the sphincter vesicæ cannot be opened simultaneously. Some of our patients

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voided immediately after the proctoclysis tube was removed, and some, on the other hand developed retention three to six days post-operatively after the use of the rectal tube to relieve distention. In one case in which repeated bouginage for rectal stricture was done, retention developed each time the large bougie was left in the rectum.

(6) *Incidence of Type of Operation.*—

TABLE II

Type of Operation	Cases	Retention	Per Cent.
Appendectomy.....	131	26	19.8
Gall-bladder.....	51	8	15.8
Hernia.....	70	11	15.7
Hæmorrhoid and rectal.....	77	11	14.3
Gastric.....	32	12	37.5
Extremities.....	109	0	0.0
Breast.....	38	3	7.8
Chest.....	29	2	6.5
Goitre.....	25	1	4.0
Major abdominal.....	55	4	12.7
Hysterectomy.....	10	2	20.0
Head and neck.....	94	2	2.1

Thus we find an incidence of post-operative retention after abdominal operations of 18.6 per cent., after rectal and inguinal operations, of 14.9 per cent., and after operations on the rest of the body, of 2.7 per cent. The incidence after gastric operations seems highest probably due to the fact that they require the longest and deepest anæsthesia, always require ether and produce the most profound shock. This type of operation prevents the patient from using his diaphragm and abdominal muscles for exerting pressure on the bladder. Then too the type of patient who suffers from ulcer is usually high strung and nervous with a slightly imbalanced vegetative nervous system. Operations involving the pelvic organs show the next greatest frequency of post-operative retention. They actually damage part of the nerve supply to the bladder and probably directly interfere with the reflex arc of micturition.

Retention is surprisingly common after appendectomies. One might explain this by the nearness of the bladder to the operative field, but it is my belief that this and the injury to the inguinal nerves as in hernia only partially explain this high incidence. Another explanation can be found in the fact that we give proctoclysis routinely in all appendectomy cases. It has also been noted that retention usually occurred in those patients who seemed to have acute symptoms without much pathology in the appendix.

These figures demonstrate that opening the abdomen, and nearness of the field of operation to the bladder and rectum have a definite influence in retention. Operations on the head, neck and chest, and extremities were followed by retention in only 2.7 per cent.

Experimentally we studied the condition of the bladder in retention by means of the cystometer which has been constructed according to Muchat's

and Johnston's modification of Rose's cystometer. This instrument is best adapted to determine intracystic pressure, because it permits of bladder-pressure readings at different degrees of filling. We plotted curves of intracystic pressure in twenty humans and determined intracystic pressure approximately 300 times in dogs under many different conditions.

At first I will show a normal intracystic pressure curve. (Fig. 1.) The bottom curve represents the tonus of the bladder muscle and this pressure averages about 10 millimetres of mercury. The bladder capacity averages around 500 cubic centimetres but some normal bladders can hold as much as 1,100 cubic centimetres without discomfort. The next higher curve indicates

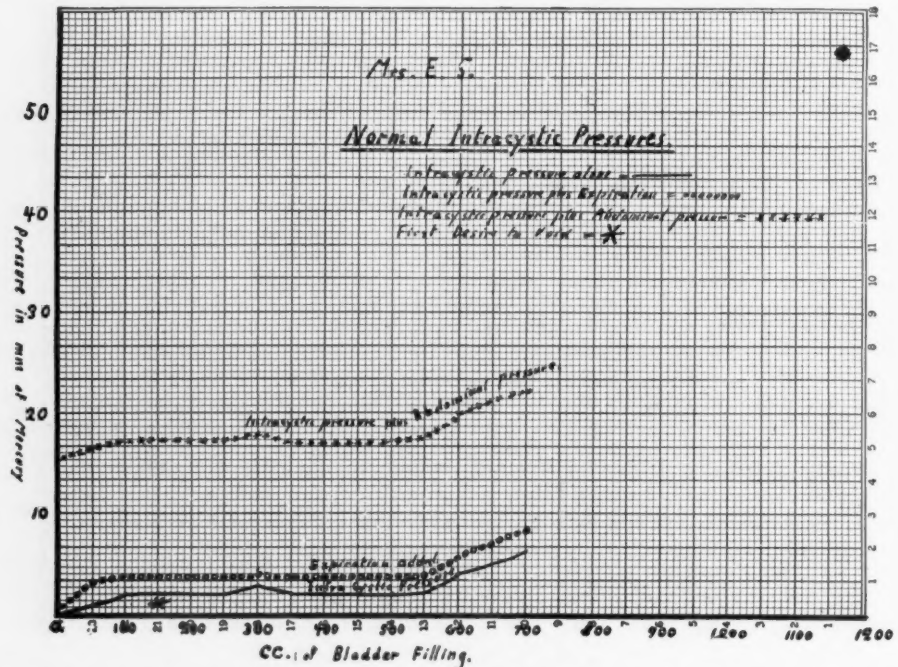


FIG. 1.—Mrs. E. S., thirty-eight. Operation for umbilical hernia under spinal anaesthesia. Pressures were taken thirteen days after operation when normal bladder function was established. She voided 450 cubic centimetres before the catheter was introduced.

the additional pressure which is obtained on deep breathing, the pressure rising on expiration.

The uppermost curve indicates intracystic pressure reinforced by abdominal pressure. This pressure is obtained by the patient's voluntary attempt to void and is usually about 20 to 30 millimetres of mercury higher than the bladder pressure alone. The effect of abdominal pressure upon intracystic pressure is another important factor in the production of retention. In plotting intracystic pressure curves we always carefully note the degree of filling of the bladder at which the patient has the first desire to void. This usually occurs at about 150 to 200 cubic centimetres of filling.

If we now consider the chart of a patient with retention, we see a low curve together with an increased capacity of the bladder, demonstrating

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decreased tone of the bladder muscle. (Fig. 2.) There is no rise in pressure on the attempt to void. Vigorous efforts of the patient to bear down upon the bladder are without success. The first desire to void is either entirely absent or it does not develop until the bladder is filled up to 500 cubic centimetres, revealing a disturbed sensibility of the bladder.

With our own clinical and experimental data in mind, we will now briefly review the physiology of the bladder. The function of the bladder is to retain urine passively and to expel it under voluntary control. This makes the bladder a vegetative organ with a partially voluntary control, and in this lies the complexity of the problem of micturition. The bladder for the same

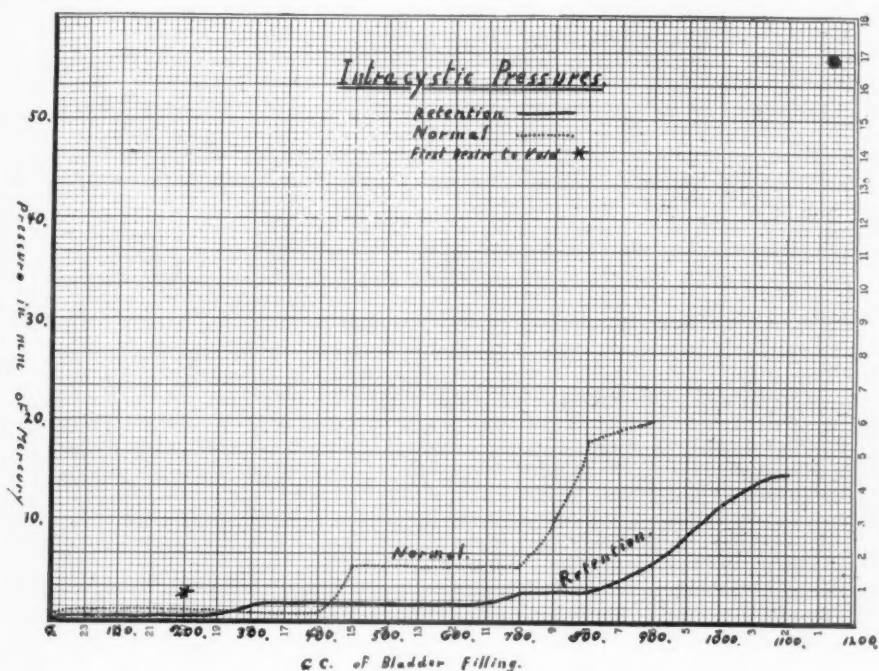


FIG. 2.—Mr. M., forty-seven. Retention developed after radical excision of carcinoma of rectum. Spinal anaesthesia. The normal bladder-pressure curve was taken eighteen days after the pressure curve with retention.

reason is the organ in the body most often affected by neurosis and very frequently pictures a person's vasomotor and vegetative make-up. Take the person who cannot void in the presence of another from the traditional sense of shame. Many people cannot void in the recumbent posture, because they associate this with bed-wetting, for which they have suffered much discomfort in early infancy. Micturition is autogenetically very closely related to the sexual act. The same nerve which causes micturition will cause ejaculation in man. The pelvic nerve which causes erection also causes emptying of the bladder. In children the act of micturition produces a sensation similar to the sexual act and this condition may persist in later life as a neurosis. In grown-ups we have a synergy between automatic and voluntary micturition.

Anything which disturbs this synergy will produce a bladder dysfunction, be it enuresis, retention, or an irritable bladder. The bladder thus may easily become a highly neurotic organ because it is supplied by such a neuropsychical mixture of automatic, autonomic, and voluntary nerves and also because it is related mentally and somatically to the sexual sphere.

There are three sets of nerves to the bladder. (Fig. 3.) The sacral autonomic nerve supply through the pelvic nerve causes contraction of the detrusor and relaxation of the internal sphincter, while the sympathetic through the hypogastric causes relaxation of the detrusor and contraction of the internal sphincter. The parasympathetic nerve is the nerve of bladder emptying and the sympathetic the nerve of bladder filling. The rôle played

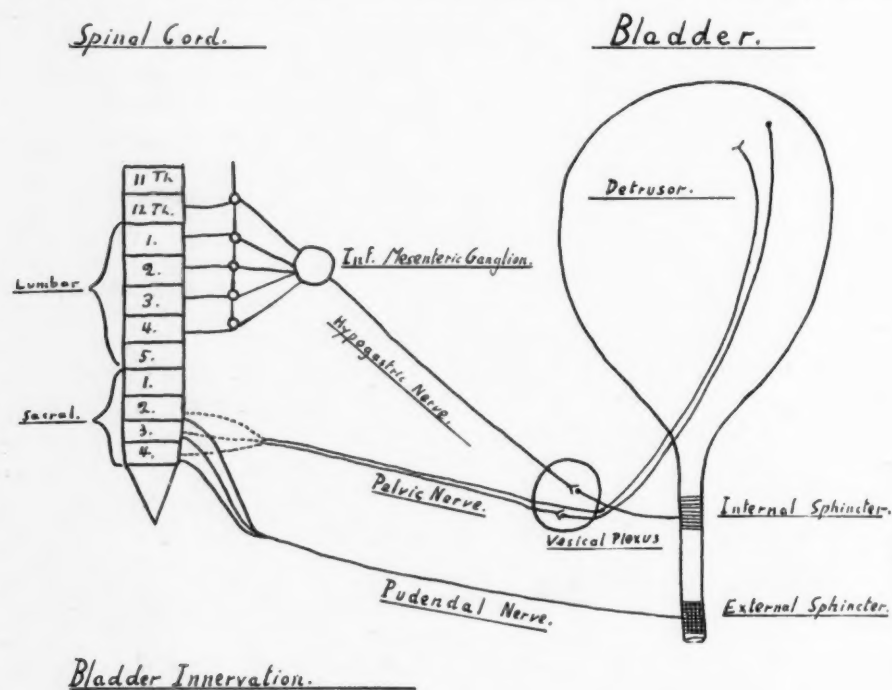


FIG. 3.—Diagrammatic representation of the bladder innervation.

by the pudic nerve, the somatic nerve, in micturition is interpreted variously by different authors. Most of them agree that it innervates the external sphincter, and thus by voluntary control can prevent leakage of urine. They also agree that it carries sensory fibres and thus acts as the sensory nerve to the bladder. Besides a cortical centre for bladder control there is probably also a centre in the mid-brain, for changes of mood have a definite influence upon bladder function. Mood is as important for voiding as for sex function.

We can thus easily see why it is so difficult or almost impossible to explain the cause of post-operative retention by any single factor and why there are so many different theories. Most authors do agree, however, that an over-balance of the sympathetic nervous system constitutes at least one big factor.

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Considering the cross-innervation of the bladder, this seems quite plausible. The proof of this theory lies in the success obtained in treatment of the condition by several European authors from the use of pilocarpine.

After careful analysis of the clinical and experimental material, it would be erroneous, however, to attribute all retention to this one cause for there can be no doubt that such factors as anaesthesia, post-operative morphine medication, proctoclysis and the opening of the abdomen also play some part in causing this dysfunction. Of course, anaesthesia, morphine, and proctoclysis might also be linked to the disturbance of the vegetative reflexes either by interruption or by a transient post-anaesthesia acidosis. Morphine, as has been shown by animal experiments, may cause a spasm of the internal sphincter. Proctoclysis by the rectal tube upsets the normal reflex of the sphincter vesicae. The effect of opening the abdomen upon retention is purely mechanical and has nothing to do with the vegetative nervous system. The incision of the abdominal wall produces in the latter a tendency to splint itself involuntarily, thus incapacitating the so-called "bauchpresser" which is of such importance in exerting pressure on the bladder. The fear of pain in contracting the abdominal muscles leads us to the last important factor in retention, namely, the psychic element. Sachs believes that the pain connected with contractions of the abdominal muscles and even the fear of such pain leads to faulty innervation and to a spasm of the voluntary or perhaps even of the involuntary sphincter and thus to retention.

Summarizing our own clinical observations with regard to the etiology of retention we can say that it is caused not by any single factor but that it depends upon several and that at different times one factor or another may predominate. The reflex of micturition is disturbed by (1) vegetative imbalance, in which anaesthesia, post-operative medication, or proctoclysis may play a part; (2) mechanical interference with the "bauchpresser" and (3) by the psychic make-up of the patient.

When we now turn to the treatment of this condition, aware of the complexity of the problem, we are quite prepared to find many obstacles. There have been almost as many treatments as authors reported writing on this subject. In every patient with retention certain classic measures which are known to every nurse and orderly are tried first. These measures, however, often fail, and then we are forced either to catheterize the patient or to try some of the various methods which will be discussed below.

Sachs, who believes in the psychic cause of retention, treats all his patients with psychotherapy and claims good results. Lampert, Henrickson and other Russian, German and French investigators, believing firmly that the cause of retention is a disturbance of the parasympathetic nervous system, treat their cases with pilocarpine.

Those who believe in a diminished sensibility of the bladder mucosa as a cause use intravenous urotropin and cytotropin with apparent success and others who believe in spasm of the internal sphincter as the sole cause of retention relieve this spasm by administration of potassium acetate. Pituitrin,

which increases the power of the bladder muscle, is used by still another group.

In reviewing the different methods and their varied results, one is rendered very skeptical as to the possibilities of a specific treatment for this condition. From 300 intracystic pressure readings with the cystometer in dogs and from my treatment of thirty-seven patients with retention, I have obtained the following results:

The first chart shows the effect of various drugs upon the dog's bladder. (Fig. 4.) Female dogs were used in all the experiments. The catheter was introduced without anaesthesia and the intracystic pressure curves taken with the dog lying down. The normal curve as represented on this chart shows

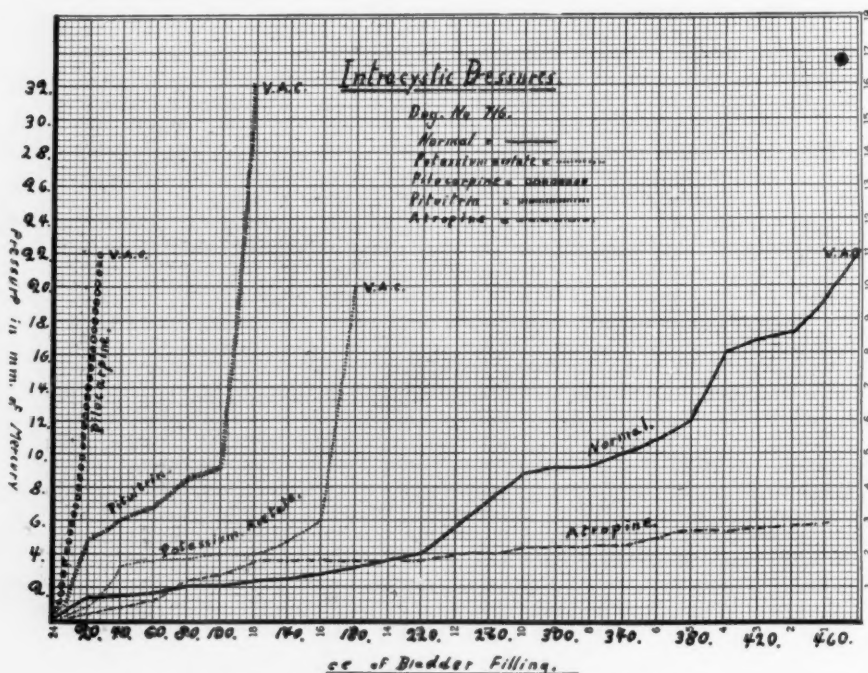


FIG. 4.—Intracystic pressure curves of a female dog.

the bladder capacity of 480 cubic centimetres and a maximum pressure producing micturition around the catheter to be 22 millimetres of mercury. The dog, like the human being when about to urinate, attempts to assume the standing posture, in which the bladder pressure always rises at least another 10 millimetres of mercury. Dogs differ from human subjects, however, in that after intracystic pressure exceeds a certain level they always void around the catheter. This point of voiding represents the tonus of both the internal sphincter and of the bladder. In only one human being have I encountered a sphincter which permitted voiding around the catheter, suggesting that if the human bladder functioned like that of the dog there would be no post-operative retention.

Intravenous injection of pilocarpine grain 1/12 will produce a curve as

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shown on the chart. A similar curve was obtained by subcutaneous injection of 10 milligrams of acetylcholin. Pituitrin when injected subcutaneously also causes increased bladder tonus in dogs. Potassium acetate in a 1:15 dilution if introduced into the dog's stomach will increase the bladder-pressure.

It would be too tiring here to review the many different curves which were obtained by animal experimentation, and I will therefore review briefly the effects of a few drugs upon the human bladder. Pilocarpine given intravenously in doses of g. $\frac{1}{8}$ or more would be the best and most direct way of combating retention. I have tried pilocarpine intravenously and hypodermically in smaller doses in humans and I got only a slight rise in pressure. If the larger doses are used there is considerable abdominal pain, much increase

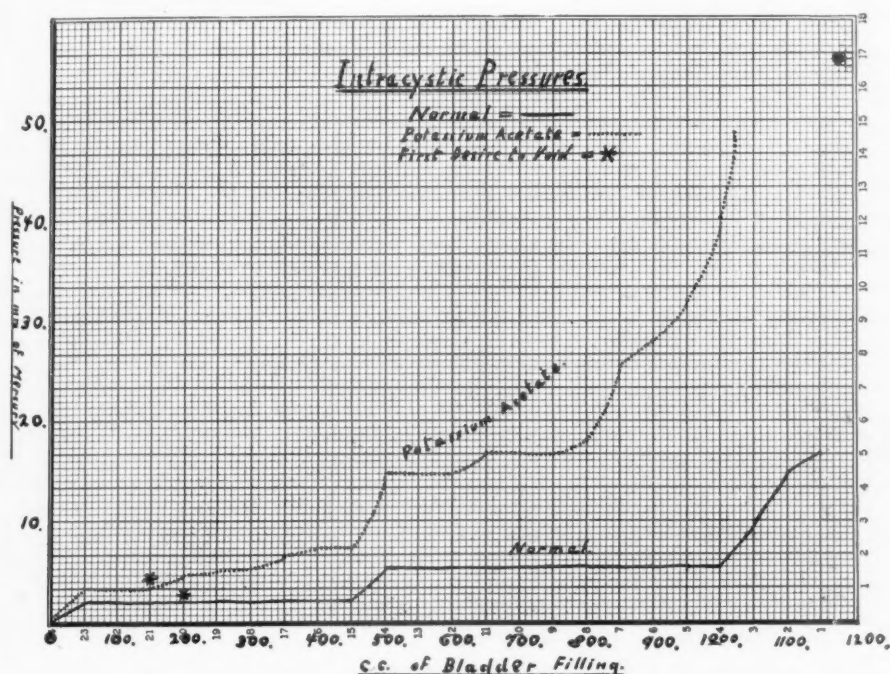


FIG. 5.—Mr. G. F., sixty-three. Retention developed after posterior resection of carcinoma of rectum. Potassium acetate ounces ss. every one half hour for eight doses (1:15) was given and then the above intracystic pressure was taken. The normal intracystic pressure curve was taken thirteen days later.

in peristalsis, and profuse perspiration; there is also grave danger of pulmonary œdema. I believe the increased peristalsis and the pulmonary œdema are sufficient contraindication to prevent its use in most cases. Acetylcholin when used in therapeutic doses has only very slight influence upon the bladder-pressure. Potassium acetate when given in dilution of 1:15 in doses of one-half ounce every half hour caused a definite rise in bladder tonus. (Fig. 5.)

My own treatment in the present series has been based upon the theory that involves not one but several factors. Psychological treatment was carried out by talking to the patient and dispelling his fears, and by assuring

him if he could not void a painful catheter might have to be used. Frequently the patient voided after this talk. To correct the sympathetic overbalance and reflex disturbance, the proctoclysis tube or rectal tube should always be removed. Potassium acetate, which is both a parasympathetic stimulant and diuretic, should be given by mouth. The lack of the "bauchpresser" is the most difficult factor to correct, but it can be at least partially supplanted by firm pressure over the lower abdomen. I have proved, by means of the cystometer, that such pressure will increase intracystic pressure about 10 to 20 millimetres of mercury.

My reasons for preferring potassium acetate as an adjuvant to the psychic and mechanical treatment are the following: (1) It is comparatively easy to take; (2) it is absolutely harmless; (3) experiments have shown that it increases the tone of the detrusor muscle of the bladder and it has a definite diuretic action; (4) it is a parasympathetic stimulant.

The typical action of the acetate was as follows: As soon as retention was established, the patient was given one-half ounce of a 1:15 solution of liquor potassii acetatis by mouth every half hour for eight doses. Usually within this time and occasionally as late as one hour after the last dose the patient began to void anywhere from 200 to 700 cubic centimetres and he would continue to void almost every three hours for the next twelve hours.

About one-half of the eighty-one cases of retention were treated in this way, with the following results:

Before this special study was made approximately 90 per cent. of all cases of retention were catheterized. During the first half of the period in which this study was conducted about 60 per cent. of all patients with retention were catheterized and during the last half of this period, 28 per cent. of all retention cases needed the catheter. Potassium acetate was used in thirty-eight of these cases and it was successful in twenty-six or 69 per cent. of the cases. These figures prove that much can be done in the treatment of retention, but also that the above treatment is by no means ideal.

Summary.—With regard to etiology we can say that retention is caused not by any single factor but that it depends upon several and that at different times one factor or another may predominate. The reflex of micturition is disturbed by (1) vegetative imbalance, in which anaesthesia, post-operative medication, or proctoclysis may play a part; (2) mechanical interference with the abdominal pressure or "bauchpresser," and (3) by the psychic make-up of the patient.

Treatment was carried out with these three factors in mind. Vegetative imbalance was combated by stopping proctoclysis and giving potassium acetate, the mechanical factor was overcome by pressure over the lower abdomen and by deep inspirations, and finally the psychic derangement was corrected by psychotherapy.

By this treatment the percentage of catheterization was reduced from 90 per cent. to 28 per cent.

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TRANSACTIONS

OF THE

PHILADELPHIA ACADEMY OF SURGERY

STATED MEETING HELD DECEMBER 5, 1932

The President, DR. JOHN SPEESE, in the Chair
CALVIN M. SMYTH, JR. M.D., Recorder

BURN-SCAR CONTRACTURES OF UPPER EXTREMITY

DR. ROBERT H. IVY and DR. LAWRENCE CURTIS presented two patients, showing correction of burn-scar contractures of the upper extremity.

CASE I.—A girl, aged eleven years, was admitted to the Graduate Hospital September 3, 1931, with severe burn scars of the left arm and axilla, extending over the pectoral and scapular regions. The left wrist and elbow were fixed in flexion and the arm from the shoulder to the elbow was bound to the side of the chest by a continuous band of scar tissue. The skin about the elbow showed desquamation, and was ulcerating in several areas with granulations. The burn had been sustained twenty-one months previously.

From September 4, 1931, to May 27, 1932, a series of operations was performed to correct these deformities. The first operation consisted in freeing the left arm from the side of the chest. The web of tissue joining the two was divided from the shoulder to the elbow, until free movement of the shoulder-joint was obtained. The remaining raw surfaces on the side of the chest and inner aspect of the arm were partly closed by undermining and bringing the edges of the wounds together. A gap high up in the axilla was filled with a full-thickness skin graft from the abdomen. Scarlet red ointment was helpful in healing remaining granulating surfaces. Ultra-violet radiation was also used twice weekly. On readmission to the hospital February 18, 1932, the axilla and arm having completely healed, and the patient being able to raise the arm above the level of the shoulder, attention was directed to the contracture of the elbow. February 19, 1932, a vertical tube of skin and subcutaneous tissue about twelve inches in length was made on the left side of the back. (Fig. 1.) April 1 an area of tissue connected with the lower end of the tube was outlined, partly raised and sutured back in position. April 15 the left elbow was straightened out after wide excision of adherent skin and scar tissue and lengthening of biceps tendon. The lower end of the tube-pedicled flap on the back was raised and carried over to be sutured to the edges of the raw surface on the flexor aspect of the elbow. May 27 the upper end of the tube was detached from the back, the whole tube opened out and sutured to cover the remaining raw surface about the elbow. June 6, 1932, patient was discharged from the hospital, wound nearly healed and with ability to almost fully extend left elbow. (Fig. 2.) Occupational therapy has brought about further improvement. The problem of the wrist and hand remains.

CASE II.—A girl, aged nine years, was admitted to the Graduate Hospital in October, 1931, with a band of dense scar tissue on the anterior aspect of the right axilla, resulting from a burn when three and a half years old. The scar restricted movement of the shoulder so that the arm could not be

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raised farther than a horizontal position. This was corrected by the Z plastic operation described by McCurdy (McCurdy, S. L.: Surg., Gynec., and Obst., vol. xvi, p. 209, 1913), in which it is not necessary to resort to skin grafting. An incision was made along the edge of the scar band (not across it), and from the ends of this line incisions were made at about right angles to it, one being back across the arm and the other on the front of the chest. By undermining, two triangular flaps were formed and transposed. This procedure effectually obliterated the scar band and released the shoulder-joint so that after healing normal movement of the arm was restored.

DR. ROBERT IVY said both of these cases were treated in the acute stages of the burns with the limb extended in the hope of avoiding contracture. In spite of this, a few months after removal of the extension apparatus the contractures occurred.

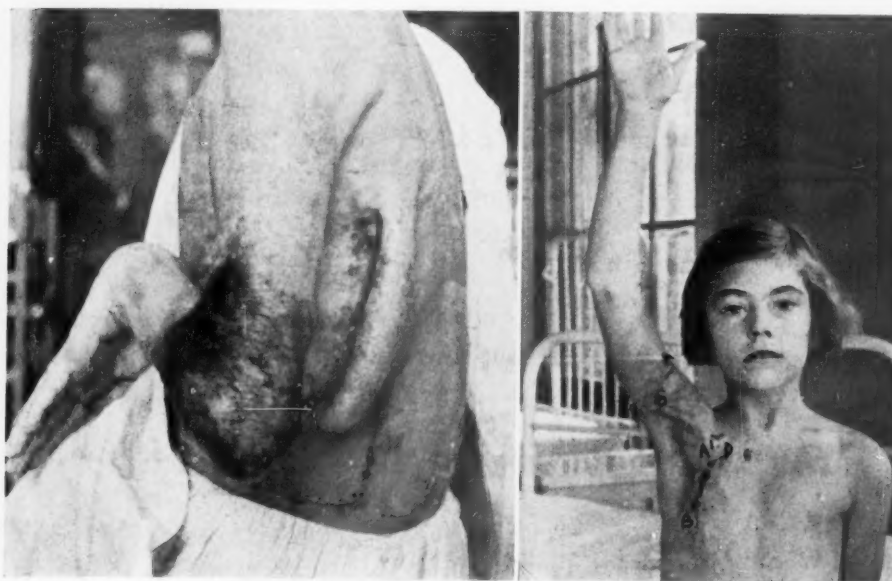


FIG. 1.—Burn scar at elbow and axilla, tubed pedicle at back.

FIG. 2.—Result of series of plastic operations on the burn scar shown in Fig. 1.

DI-VINYL ETHER—A NEW ANÆSTHETIC

DRS. I. S. RAVDIN, GEORGE P. MULLER, and, by invitation, DRS. SAMUEL GOLDSCHMIDT, BALDWIN LUCKE and C. G. JOHNSTON presented a preliminary report on the results of a clinical and experimental study of Di-Vinyl ether, a new compound which is capable of producing surgical anaesthesia. The outstanding features of this preparation are the rapid induction, rapid recovery, and singular freedom from unpleasant after-effects. Regarding toxicity it appears to stand between ethyl ether and chloroform. The experimental studies are being carried out in the laboratories of Research Surgery and of Physiology at the University of Pennsylvania and to date have included observations of the effect upon the liver, the concentration in the blood required to maintain anaesthesia and the margin of safety between

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anæsthetic and lethal doses. The experiments have all been conducted with careful controls.

Doctor Muller and Doctor Ravdin have administered or caused to be administered this anæsthetic to eighty-two patients varying in age from one to eighty-three years. The type of operation included practically all general surgical conditions except those of the biliary tract which were excluded on account of lack of accurate knowledge of the effect upon the liver.

The average time required to induce anæsthesia was forty seconds and most patients were able to answer questions intelligently in a few minutes after the administration was terminated.

Further studies are necessary before the investigators are ready to recommend this preparation to the profession, but it would appear to possess some of the features necessary for the long-sought "ideal anæsthetic."

REPAIR OF UNUNITED FRACTURES BY LATERAL APPPOSITION AND INTERNAL FIXATION

DR. A. BRUCE GILL said that this principle is not new, but it may probably be applied with advantage more frequently than is now done.

When it is possible to convert an old ununited fracture into an oblique fracture, to secure a lateral apposition, and to fix the fragments securely together by screws union is more certain than by any other method of operation. Furthermore, the technique of the operation is easier and simpler than the various types of bone-grafting operations. While this method of operation applies particularly to fractures of the tibia, the femur, and the humerus, the same principle of operation with slight variation can be applied in cases of non-union of the bones of the forearm. A few years ago on examining his records to determine the end-results of operations for this condition the speaker learned that he had obtained union in only 50 per cent. of the cases by the use of intramedullary grafts, inlay grafts and osteoperiosteal grafts. About four years ago he began to employ a different method and since then has had no failures. The radius or the ulna is exposed. The periosteum is incised longitudinally and separated from both fragments for a distance of three inches from the site of the fracture. Both fragments are then split longitudinally with a motor saw along the narrow side of the bone. The superficial portion of the fragment, consisting of at least one-half the entire thickness of the bone, is removed. The entire piece, whether taken from the upper or the lower fragment, is then employed as a large, broad, bone graft. The fragments are brought into proper alignment and this bone plate is fastened to both fragments securely with metal screws. The portion of bone removed from the other fragment is discarded and in some instances in fractures near the lower end of the radius the superficial part of the lower fragment is elevated by making a green-stick fracture at its base and the bone plate is inserted beneath it. In such case the screws pass through three pieces of bone in the lower fragment. The periosteum is sutured over the bone plate. The arm is dressed in a plaster bandage. If

BILATERAL EMPYÆMA

there is separation of the fragments in these cases of non-union due to absorption of the ends no attempt is made to bring the ends together. The large bone plate spans the gap between the two bones. Patients operated on in this manner have been able to return to hard work three months after the operation. Metal screws are used in preference to bone grafts because the latter are more fragile and apt to break. The screws remain permanently in place. They become completely covered with bone formed underneath the periosteum.

SPONTANEOUS PNEUMOTHORAX

DRS. GEORGE P. MULLER and FRANCESCO MOGAVERO read a paper with the above title.

BILATERAL EMPYÆMA

DOCTORS MULLER and MOGAVERO reported the case of a woman, aged thirty-one years, who was admitted May 21, 1931, to Misericordia Hospital in the service of Doctor Muller with the chief complaint of chills, fever, pain in right side of chest and cough with expectoration. She was apparently healthy until May 17, when she was taken ill with a "cold," cough, fever, headache and general malaise. She spent one day in bed and was up and around for several days, and then suffered a relapse and was taken suddenly with chills, fever, pain in right chest, cough with copious expectoration which was blood streaked.

When admitted she was markedly dyspnoëic, suffering a great deal of pain with each respiratory movement. Respirations were rapid and shallow due to pain. Her lips were slightly cyanotic. The chest anteriorly revealed a lagging over the right side on expansion, impaired resonance in the right middle lobe, bronchial breathing and increased vocal fremitus. The upper right lobe showed numerous coarse râles. In the left lobe were found many scattered coarse râles.

Temperature, 101° ; pulse, 140; respiration, 46.

Diagnosis.—Pneumonia involving the lower and middle right lobes. At the time of admission she was six months pregnant. On the third day thereafter she gave birth to a living child with intact membranes. The placenta came away spontaneously. The fœtus died shortly after delivery.

The patient's condition for the next ten days was poor. Examination showed a left empyæma present.

June 3, thoracentesis was performed and 275 cubic centimetres of pus removed from the left chest at the eighth interspace, posteriorly. The following day, the patient became very dyspnoëic and thoracentesis was repeated with removal of 400 cubic centimetres of pus from the left chest with some relief. The existence of a bilateral effusion was determined. (Fig. 3.)

On June 5, left thoracotomy was performed. The drainage tube was attached to a Hart apparatus for tidal irrigation as modified by Overholt. The solution used for irrigation was normal salt solution.

After operation, the patient was improved sufficiently to permit right thoracotomy which was performed June 15. The tidal irrigation was stopped on the left side, closed drainage still carried out, placing end of tube under water in a bottle. Blood transfusion of 500 cubic centimetres of citrated blood given. The patient did well, closed irrigation was stopped and drainage into dressings permitted. She was discharged August 4, 1931, with a

final note that the wounds were healed, slight amount of fluid present as reported by last X-rays. Temperature was normal. (Fig. 4.)

Six months later the patient reported that she had been well since discharge from the hospital.

DOCTOR MOGAVERO added that bilateral empyæma is not an infrequent complication following pneumonia. Most authors agree that empyæma is bilateral in less than 5 per cent. of the non-fatal sporadic cases. In 603 autopsies of empyæma cases, Dunham found that 43 per cent. were bilateral, Hellen states that 7.7 per cent. of all empyæma cases are bilateral; Tod that 2.0 per cent. and Tholt 3 per cent. The majority of these occur, according to Curtis and Bowman, during the early decades of life, and males are affected in 65 per cent. of the cases. Graves reports that it is frequent in children under ten and in adults beyond middle life. He reports a series of twenty cases spread over the various age groups thus: Thirteen, or 65

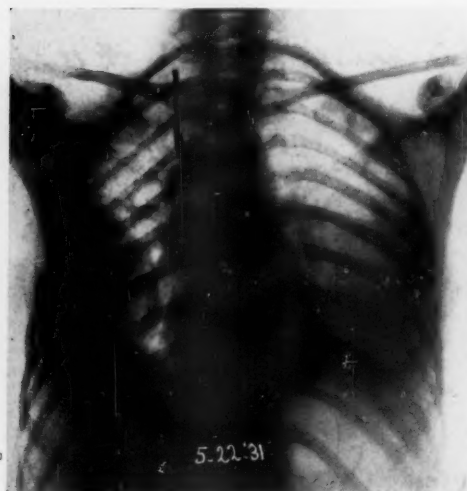


FIG. 3.—Showing bilateral empyæma.

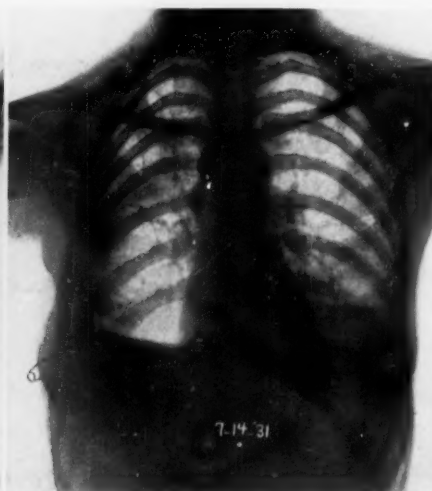


FIG. 4.—End-result.

per cent., in first decade. Three, or 10 per cent., in second decade. Two, or 10 per cent., in third decade. Three, or 15 per cent., in fourth decade.

Scanlan, in 1928, collected in the literature up to that time 248 cases, Graves reported in 1928 twenty cases, and Keyes forty-four cases, having a total of 312 cases. Graham states that bilateral empyæma occurs more frequently in the streptococcus cases (hemolytic) than in the pneumococcus. However, others disagree; Graves found that staphylococcus and pneumococcus were the predominating organisms. Keyes, in his series, found that the pneumococcus was most commonly present, Curtis and Bowman that the pneumococcus was found in 70 per cent., the streptococcus in 14 per cent. In 1917-1918 there was a reversal of these figures, 73 per cent. due to streptococcus and 23 per cent. to pneumococcus. Curtis and Bowman found that the staphylococcus was a rare offender and report a case of staphylococcus empyæma following a carbuncle of the neck.

BILATERAL EMPYÆMA

Most writers found that three-fourths of the cases followed bronchopneumonia and that it may occur as a complication following influenza, measles, scarlet fever and puerperal sepsis. Bilateral empyæma occasionally follows when the pneumonia is demonstrable in but one lung. In Keyes' series of cases, the death rate was 19.5 per cent., and in Fabrikant's series of 118 cases, 37 per cent.

Treatment of bilateral empyæma varies with every writer and the following will give a general idea of methods employed: Hedbloom advocates bilateral simultaneous closed drainage; Auer, closed drainage, aspirating the largest one first, and then an open drainage of this side and a closed drainage of the other. Markley in his case did, first, bilateral aspiration and then bilateral rib resection; however, did not state whether open or closed type used. Scanlan in his case employed bilateral aspiration, then a bilateral thoracotomy, these at three-day intervals; Beck's case, bilateral thoracotomy. Ravnitzky and Bogia report two cases, in one a bilateral rib resection with a twenty-six-day interval and in the other, one side aspiration and other side rib resection thirty-seven days later. Matthews advocates aspiration and closed drainage; Graves, rib resection, open drainage type, interval of five days. Keyes advocates a high fluid and caloric intake, and simultaneous drainage. He states that the patient is not relieved a great deal after the first thoracotomy and tends to remain very little changed until after the second thoracotomy, that delay seems to accomplish little but weaken the powers of resistance. If delay must be carried out and empyæma of both sides is equal, operate on the left one first, thus relieving cardiac embarrassment; if empyæma is unequal, operate on the larger one first. The initial drainage is to be closed type to fixed things and then open type. Curtis and Bowman performed a bilateral interval closed drainage, later bilateral rib resection and unilateral phrenic exeresis; the interval between thoracotomies was nine days. Beck reports a case of bilateral empyæma complicated by childbirth during attack of influenza. The woman was thirty-four years old, pregnant eight months, giving birth to normal living child at the time. He states that nearly always the mother and child die. He advocated rib resection with closed drainage, stating that both sides should not be drained simultaneously, but to give the lung a chance to expand; the interval in his case was twenty-four days.

DR. DAMON B. PFEIFFER recalled two cases of acute pneumothorax, both of whom presented at the onset all the symptoms of abdominal catastrophe. The first patient was a young man who had suddenly developed epigastric and right-sided abdominal pain. The temperature and pulse were about normal and the respirations moderately elevated. The abdominal muscles were tense, particularly on the right side. The first impression was perforated ulcer. Percussion of the chest yielded a high-pitched, tympanitic note on the right side with a complete absence of breath sounds. The heart was shifted to the left. The patient was removed to the hospital. X-ray examination gave a characteristic picture of a small collapsed lung lying

tight against the hilum. The abdominal symptoms soon passed off, the patient made a complete recovery and has remained well for six years. The second case was more recent and presented a very similar picture. The origin of the pneumothorax in both cases has remained obscure. Neither patient has presented either clinical or X-ray evidence of tuberculous involvement of the lung. There was no strain or history of accident. About nine months ago an acute pneumothorax developed suddenly in another patient during convalescence from operation for carcinoma of the cæcum. This was accompanied by collapse, dyspnoea and severe epigastric pain. It was at first thought that obstruction or some other intra-abdominal complication was going on. Examination of the chest followed by X-ray cleared up the diagnosis. The patient went on to an uncomplicated recovery and has remained well.

It might be pertinent to call attention to the simulation of abdominal disease by certain anginoid heart attacks. The older clinicians recognized this and spoke of abdominal angina. Years ago Murphy called attention to mediastinal lesions as a cause of paralytic ileus simulating obstruction. It has been of interest to note that in the present wave of so-called grippe or influenza, symptoms in many cases have strongly suggested appendicitis or other intra-abdominal surgical lesions. The differentiation has often been extremely difficult or impossible. The rôle of certain forms of pneumonia and basal pleurisy in mimicking abdominal disease is, of course, well known.

DR. GEORGE P. MULLER remarked that when he examined the first patient on admission he was certain he had a perforated peptic ulcer. Some years ago he observed a patient with violent epigastric pain in whom acute pancreatitis was suspected. Operation was not done and twenty-four hours later pain recurred and the patient died. At autopsy a ruptured dissecting aneurism of the thoracic aorta was found with mediastinum and pleura full of blood. In the second case a tumor of the thymus had perforated or ruptured. The mediastinum at autopsy contained organized blood-clots but when seen by the speaker his symptoms were those of an acute epigastric lesion, possibly pancreatitis. An X-ray of the chest revealed the true nature of the lesion.

The case of bilateral empyæma was the first one he has seen for ten years. Possibly in a similar case he would be tempted to operate in two stages with only a few days' space between them.

TRAUMATIC RUPTURE OF STOMACH, COLON AND KIDNEY

DR. WILLIAM T. LEMMON reported the case of a boy, eleven years of age, who was admitted to the Philadelphia General Hospital June 15, 1932, in the surgical service of Dr. Hubley R. Owen, about twenty hours after a fall from a board fence. He struck the anterior right lateral surface of his abdomen, his body landing in a jack-knife position across the fence. He was knocked breathless but did not lose consciousness. After sitting on the

TRAUMATIC RUPTURE OF STOMACH, COLON AND KIDNEY

curb for about fifteen minutes, he started home, aided by his playmates. He made frequent stops on account of extreme weakness and dizziness. During the night, he was very restless and suffered pain. He asked constantly for ice and ice water. He vomited several times. He neither voided nor had a bowel movement during the night. The following morning at 9:30 he passed less than 100 cubic centimetres of bloody urine. He also passed fresh blood and blood-clots by bowel. Vomiting and thirst continued. On admission to the hospital the following afternoon, the abdomen was markedly distended, tender, and rigid. The rigidity was more marked over the entire right side of the abdomen and the right loin. The percussion note was tympanitic except in the flanks, where it was flat. Feeble peristaltic sounds were heard only over the left upper abdomen. There were no visible signs of injury to the surface of the abdomen, loins, or elsewhere on the body. Temperature, 100°; pulse, 148; respirations, 22 per minute. The urine examination showed blood grossly and microscopically. The blood count revealed 11,500 leucocytes, 3,120,000 red blood-cells, and hæmoglobin of 62 per cent.

Previous to operation, 5 per cent. glucose in 400 cubic centimetres of normal saline was given intravenously. Twenty-one and a half hours after the accident, under ether anæsthesia, a left paramedian incision was made. The left rectus incision was made because of the possibility of injury to the spleen. The peritoneum was dark in color and the peritoneal cavity contained approximately 1,200 cubic centimetres of bloody fluid, blood-clots, inflammatory lymph, which had a fecal odor. Blood was present in the greater peritoneal cavity, the lesser peritoneal cavity, and in the retroperitoneal tissues on the right side of the abdomen. A systematic examination of the abdominal organs revealed the liver, spleen, pancreas, left kidney, jejunum, descending colon, sigmoid, rectum, and bladder to be uninjured. The mesentery to the terminal ten inches of the ileum was torn and that part of the ileum was dark in color, cold to the touch, and did not respond when hot packs were applied. The circulation was so badly disturbed that resection of that portion was considered necessary. The cæcum had several small complete tears, each about one to two inches in length, extending through all the coats. These openings were plugged by the mucosa and blood-clots. The cæcum was also markedly distended, dark in color, and filled principally by blood and blood-clots. A similar but less marked condition was found in the ascending colon. The right half of the transverse colon was dark in color, cold to touch, and did not regain its color after hot pack applications. The mesocolon of that part of the colon was found to be torn and bleeding. A large, dark fluctuating mass was found in the anatomical position of the right kidney. This mass extended along the course of the right ureter to the brim of the true pelvis. There was a subperitoneal rupture of the posterior wall of the stomach with a hæmatoma about two inches in length. This bleeding was controlled by two Lembert sutures. The terminal ileum, appendix, cæcum, ascending, and the right half of the transverse colon were resected. When the peritoneum, lateral to the cæcum and ascending colon, was incised and reflected medially, there was profuse hæmorrhage from the right kidney. This delayed hæmorrhage was probably due to the release of pressure and the dislodgement of clots which served to check and lessen the renal bleeding. The clots were removed from the region of the right kidney and also the lateral half of the kidney. There was profuse bleeding from the remaining portion of the kidney. This hæmorrhage was checked by clamp and ligature. The remaining portion of the kidney was

then removed. A lateral isoperistaltic anastomosis was made between the terminal portion of the remaining ileum and the proximal portion of the remaining transverse colon. Complete hæmostasis was secured and all raw surfaces were peritonealized. The peritoneal cavity was irrigated with hot normal saline. Approximately one pint of this solution was left within the cavity. The abdomen was closed without drainage. During the operation the patient received 100 cubic centimetres of 5 per cent. glucose and 200 cubic centimetres of normal saline intravenously. At the conclusion of the operation, he was given 90 cubic centimetres of blood by transfusion with immediate improvement. During his convalescence, which was uneventful, he was given blood transfusions, glucose, and normal saline. July 22, he was discharged in good condition.

This boy, approximately five months after operation, is in perfect health. An X-ray examination made before discharge from the hospital showed the terminal ileum joined to the proximal end of the remaining portion of the transverse colon. The intestinal function was normal. The pathological report of the kidney showed an acute purulent exudate, in addition to traumatic rupture and hæmorrhage. The cæcum showed gangrene in addition to ruptures and hæmorrhage.

Aristotle's observation that the intestine of a deer is so fragile that a blow will cause it to rupture without injuring the skin, is perhaps the first record of injury to the intestine following abdominal contusion without external signs of trauma. It was not until the seventeenth century, when post-mortem examinations became more common, that traumatic intestinal perforation was given its due recognition as an important surgical condition.

Moynihan states that the first laparotomy for rupture of the intestine was performed by Bouilly, in 1833. The first successful case was operated upon by Croft in 1889. Examination of the literature shows that traumatic rupture of the large intestine is much less frequent than that of the small intestine but that both may be ruptured at the same time. The reporter had not found a recorded case of rupture of the kidney complicating rupture of the colon with recovery of the patient. According to Moynihan, emphysema is the only sign that is characteristic of lesions of those portions of the bowel which are not wholly covered by peritoneum (parts of the duodenum and the ascending and descending colon). If the usual symptoms of intestinal injury and emphysema in the right flank are present, a diagnosis of rupture of the ascending colon or of the duodenum may be made. Emphysema spreading from the descending colon may be noticed first in the left flank.

The large intestine is not so frequently injured as the small intestine. In a total of 221 cases collected from London hospitals, Berry records 177 injuries of the small intestine, twenty-nine of the duodenum, and fifteen of the large intestine. Other statistics give practically identical results.

TRANSACTIONS

OF THE

NEW YORK SURGICAL SOCIETY

STATED MEETING HELD DECEMBER 14, 1932 AT THE PRESBYTERIAN HOSPITAL
OF NEW YORK

COMPLICATIONS OF FRACTURES IN THE AGED

DR. WILLIAM DARRACH, M.D., from the Surgical Service of the Presbyterian Hospital, presented the subject of the complication of fractures in the aged. He said: Fractures in the aged are serious because of the complications. When elderly people are kept in bed, they are apt to get hypostatic pneumonia and die, so we must roll them over and sit them up as soon as possible. Four years' experience in the Fracture Ward has proved to us the truth of this idea. It has also shown us that the problem is not quite as simple as that.

There are two types of complicating conditions in which we have been greatly helped by the work of Bancroft and Stanley-Brown. In one type we find old people who have survived the first shock of their injury who, seemingly on the road to recovery, begin to get drowsy and drop off to sleep more and more frequently and more deeply. Soon they cannot be aroused and finally drift off in a quiet, peaceful death. Other groups include those who show an unhappy tendency to clot. They have one or more attacks of thrombo-phlebitis either with or without pulmonary infarction. Many of these two classes show a disturbance of the clotting index. Such cases have been very materially improved and sometimes brought back to normal by the use of sodium thiosulphate and diet. In several instances, the reaction has been startlingly satisfactory.

A simple rehearsal of other complications we have met seems to be the best method of presenting this picture.

A woman of eighty-three with a fracture of the base of the neck of the femur had marked cardiac arrhythmia. She developed pneumonia and died on the ninth day.

A woman of seventy-five with a comminuted fracture of the upper extremity of the humerus had a severe nephritis. She became irrational on her second day and died from pneumonia on her twelfth.

A man of eighty-six with a fracture of the base of the femoral neck with marked hypertension and arterio-sclerosis was awakened from a drowsy stupor twice by sodium thiosulphate, but failed to respond a third time and died on the sixty-fourth day. Autopsy showed solid bony union.

A woman of eighty-three with fracture of the base of the femoral neck developed a senile psychosis that cleared up completely on sodium thiosulphate. She died eight months later in the city hospital.

A woman of sixty-six with an intertrochanteric fracture developed a coronary thrombosis in her fourth week and died.

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A man of seventy-six with an intertrochanteric fracture of the femur did splendidly until his thirty-first day when he ruptured his gall-bladder and died within twenty-four hours.

A woman of seventy-three stood a Smith-Petersen open reduction very well until the operation was finished, when she suddenly became cyanotic and autopsy showed a large saddle clot in her pulmonary vessels.

A woman of seventy with a high fracture of the neck of the femur developed a musculo-spiral paralysis during application of a plaster case which delayed convalescence through her inability to use crutches.

A woman of seventy with a fracture low in the neck of her femur developed a noisy senile dementia requiring restraint and was sent to Bellevue.

A woman of seventy-one with an intertrochanteric fracture had a large decubitus on her leg requiring skin grafting on the ninety-ninth day.

A woman of seventy-two with a fracture of the neck of the femur, marked cystitis and incontinence, had such violent paralysis agitans that she jiggled off the adhesive together with large areas of skin.

A woman of seventy-four with a Smith-Petersen reduction of the hip developed a thrombo-phlebitis on her fifty-fourth day and had two severe cerebral attacks afterwards. She was aided by sodium thiosulphate and is now walking with solid union.

A woman of seventy-four had a Smith-Petersen open reduction and on the day after the operation developed a vaginal hæmorrhage severe enough to require packing.

A man of seventy-five with a bad prostate and uræmia fell out of bed breaking his hip which complicated his uræmia—fatally.

A woman of seventy-seven with a fracture of the neck of the femur, with bad cystitis and pyelitis, developed an acute appendix on her twenty-fourth day. A decubitus on her heel delayed her walking for many months.

A man of seventy-eight with Paget's disease and a fracture through the shaft of his femur with muscular interposition was greatly helped during his convalescence by sodium thiosulphate, but a decubitus on his heel delayed his convalescence for many months.

A woman of eighty with a fracture of the neck of the femur was given sodium thiosulphate after her second pulmonary infarction. She recovered without any more attacks.

A man of eighty-four with an oblique fracture of the shaft of the femur, bad chronic cystitis and marked arterio-sclerosis, had an attack of thrombo-phlebitis and auricular fibrillation. He also had two cerebral attacks in one of which there was marked Cheyne-Stokes breathing. He seemed greatly helped by sodium thiosulphate and walked out of the hospital with solid union.

A woman of eighty-four with a subtrochanteric fracture of the femur which was complicated by a severe uterine prolapse. She became very drowsy on her sixty-third day and on the ninety-second day developed bronchial pneumonia. Seventeen months later she was walking with a moderate limp.

A man of eighty-eight with a fracture through the base of the neck of the femur was greatly disturbed by a thrombosed hæmorrhoid which required operation.

A woman of sixty-eight had a fracture through the trochanters and a blood-pressure of 260 with high blood-sugar. She celebrated her release from her brace at the end of nine months by again falling and breaking the other hip. She succeeded in getting solid bony union in both hips.

A man of seventy-one with a compression fracture of his upper lumbar vertebra caused us great anxiety by persistent and extreme abdominal distension for the first few days.

DIAGNOSIS OF CHOLELITHIASIS

A man of eighty-one with a fracture of the pelvis was complicated by the presence of a large stone in the bladder with cystitis.

We have had the usual complications of carcinoma with pathological fractures.

A woman of sixty-eight with a fracture of the neck of the femur was greatly disturbed by herpes zoster involving the groin and buttocks.

It is difficult to predict what the complications of fractures in the aged will be.

THE DIAGNOSTIC VALUE OF BILE OBTAINED THROUGH A DUODENAL TUBE—WITH ESPECIAL REFERENCE TO THE DIAGNOSIS OF CHOLELITHIASIS

DRS. LOUIS M. ROUSSELOT and LOUIS BAUMAN presented a note stating that during the past ten years there has been a gradual accumulation of evidence by various investigators tending to show that the association of cholesterol crystals in duodenal bile and gall-stone disease is more than a coincidence.

Lyon, Hollander, Mateer and Chester Jones all felt that the presence of many clumps of cholesterol crystals probably signified the presence of gall-stones. Recently Bockus presented a large, carefully studied group of cases and concluded that the presence of cholesterol crystals or calcium bilirubin pigment or both in bile obtained by a duodenal tube was positive criteria for the diagnosis of gall-stones.

Similar studies have been repeated and somewhat elaborated at the Presbyterian Hospital during the past year and a half.* A technic has been adopted that greatly simplifies and hastens the passage of the duodenal tube. All intubations are checked as to position by using the fluoroscopical table. The identification of the crystalline elements and calcium bilirubin pigment in the bile sediment is not difficult.

Our experience has been summarized and arbitrarily divided into the following four groupings. A comparison with the X-ray findings and the operative findings is also given.

TABLE I

Cases Yielding Dilute ("A") Bile Without Cholesterol Crystals or Calcium Bilirubin

(1) Total number in group	30
(2) Cholecystogram	25
(a) Abnormal response	24
(b) Normal response	1
(c) Accurate interpretation 23 out of 25.....	92%
(3) Duodenal drainage	30
(a) Laboratory diagnosis of chronic cholecystitis with or without stones....	29
(b) Laboratory diagnosis of normal gall-bladder.....	1
(c) Cases in which failure to recover "B" bile was unexplained by operative findings	8
(d) Accurate interpretation 22 out of 30.....	73%

* Cholesterol Crystals and Calcium Bilirubinate Granules. Their Significance in Bile Obtained Through the Duodenal Tube. Louis M. Rousselot and Louis Bauman: J. A. M. A. Vol. 100, p. 254, Jan., 1933.

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TABLE II

Cases Yielding No Bile

(1) Total number in group	7
(2) Operative findings	
(a) Calculi in common duct with obstruction	3
(b) Carcinoma of the head of the pancreas.....	2
(c) Carcinoma of the papilla of Vater.....	1
(d) Cicatricial stenosis of the common duct.....	1

TABLE III

Cases Having Neither Cholesterol Crystals Nor Calcium Bilirubin in So-called "B" Bile

(1) Total number in group	14
(2) Cholecystogram	12
(a) Abnormal response	6
(b) Normal response	4
(c) Equivocal findings	2
(d) No X-ray	2
(e) Accurate interpretation 5 out of 12.....	42%
(3) Duodenal drainage	14
(a) Accurate interpretation	64%
(i.e., No stones or cholesterosis of the gall-bladder)	

TABLE IV

Cases Having Cholesterol Crystals or Calcium Bilirubin or Both These Substances in Bile

(1) Total number in group	53
(2) Cholecystogram	44
(a) Abnormal response	36
(b) Normal response	4
(c) Equivocal findings	4
(d) No X-ray	8
(e) Accurate interpretation 36 out of 44	84%
(3) Duodenal drainage	53
(a) Accurate interpretation 51 out of 53.....	96%

(These tables were shown as lantern slides)

We wish to state that this test is not done routinely on all cases of biliary-tract disease but is reserved for those cases in which the diagnosis is vague and in which there is no confirmatory X-ray evidence. It is used almost routinely in jaundice cases to establish the presence or absence of bile in the duodenum.

As a result of this study we have reached the following conclusions:

(1) The failure to obtain concentrated "B" bile after two or more drainages is suggestive of intrinsic disease of the gall-bladder.

(2) The absence of cholesterol crystals or calcium bilirubin pigment in concentrated "B" bile is fairly strong evidence against the presence of stones.

(3) The finding of cholesterol crystals or calcium bilirubin pigment in dilute "A" bile or "B" bile is almost pathognomonic of the presence of gall-stones.

WOUND INFECTION

THE CONTROL OF WOUND INFECTIONS

DR. FRANK L. MELENEY stated that in the spring of 1925 a high incidence in the Presbyterian Hospital of wound infections in clean cases led to the careful study of wound infections. It appeared that the percentage of infections was much higher than any one had suspected, and each year the study has been of such interest that it has been continued. Such a study tends to improve the sterile technic of the service and encourages care in the making of accurate observations on wound healing.

During the first spring the immediate problem was to find the cause of the hemolytic streptococcus wound infections. There were nine of these in the first five months of 1925. In searching everywhere for the hemolytic streptococcus we found that there were 33 per cent. of carriers among the operating personnel. Right after this survey had been made, another hemolytic streptococcus infection developed in a hernia. It was found that three of the persons on the operating team had hemolytic streptococcus in the throat and one of them, the instrument nurse, had them in the nose as well. (At that time we were masking the mouth rather indifferently and not covering the nose at all.) Curiously enough, the patient also had hemolytic streptococcus in his nose and throat. With all of these strains we immunized rabbits and determined by agglutinin and absorption of agglutinin tests that the strain recovered from the wound of the patient was identical with the strains from the nose and throat of the instrument nurse and different from those from the patient's own nose and throat and the throats of the operating surgeons.

Ever since then we have strictly masked nose and mouth of every one entering the operating rooms, not only the sterile operating team but anæsthetists, unsterile nurses and orderlies. There was an immediate disappearance of hemolytic streptococcus infections and there have only been sporadic cases since. With sporadic cases there is a seasonal incidence of hemolytic streptococcus wound infections, there being eight times as many in the first six months of the year as in the last six months, but, with hemolytic streptococcus wound infections reduced to a minimum, this does not hold true for wound infections in general for a summary of seven years shows that the monthly incidence hardly varies at all.

In a search for other sources of infection we have taken into account the nature of the bacteria found. For example, in a representative year (1930) of the total number of species found on culture there were: Hemolytic Streptococcus, 4 per cent.; Non-hemolytic Streptococcus, 10 per cent.; Hemolytic Staphylococcus aureus, 15 per cent.; Staphylococcus aureus, 20 per cent.; Staphylococcus albus, 22 per cent.; B. coli, 7 per cent.; B. subtilis, 6 per cent.; B. proteus, 1 per cent.; B. pyocyaneus, 1 per cent.; Diphtheroids, 5 per cent.; and others, 4 per cent.

Other sources of infection which seem to be important are: (a) materials, instruments and solutions; (b) skin of the patient; (c) hands of the operators; and (d) air of the operating room.

Cultures of the materials have uniformly yielded no growth. As skin antiseptics we compared iodine with mercurochrome-acetone-alcohol in a series of patients. We snipped bits of skin from the hair line of hernias and obtained growth in eight out of ten prepared with iodine and in nine out of ten prepared with mercurochrome. The organisms found were chiefly staphylococci and spore forming organisms. Of these, two of the iodine cases had trivial infections and one of the mercurochrome cases had a serious infection. Since then we have experimented on animals in a similar manner with all of the advocated skin antiseptics and find that none really sterilizes the skin. Probably organisms in deep hair follicles and sweat glands are not reached by the antiseptics. Until we have a skin antiseptic which will sterilize the deep layers of the skin, that will always be a source of contamination.

In studying the source from the hands of the operators we have found that after a dressing without gloves, even though great care is taken, organisms from the infection are picked up by the hands of the doctors and nurses.

In studying the contamination from the air we exposed culture plates and found that down in the old hospital, with the operating rooms on the ground floor, two colonies of bacteria grew out on the plates for every minute of exposure. When we moved uptown and tested the operating rooms on the sixteenth floor supplied with filtered air, this figure was cut in half. When we compared a room in which an operation was going on, with people moving about and doors opening and closing, with a corresponding operating room in which there was no operation going on and no moving about, we found that there were ten times as many colonies on the culture plates from the active room as on the plates from the inactive room.

The study showed further that drained wounds are more apt to become infected than undrained wounds but we are not sure whether this is due to the drains or to the nature of the condition for which the drains were used.

Hematomas, however, markedly increase the percentage of infection. If not infected at the time of the first dressing, many of these become infected later.

Certain types of operation seemed to favor wound infection. Up to 1929, a particularly high incidence of infection occurred in radical mastectomies, thyroids, open reduction of fractures, recurrent and ventral hernias, double operations and excision of lipomas. There seemed to be a plausible explanation for all but the thyroids. In this group we were getting not only a high incidence of infection but many hematomas. Most of the thyroids were being done by the two surgeons connected with the thyroid clinic. In the summer of 1929, in the absence of one of these surgeons, one of the staff, who had recently come from another clinic where silk was being used more generally, operated on five thyroids and used silk instead of catgut. The soft, clean healing of these wounds was seen by the second thyroid surgeon and he decided to try it. He operated on ten cases with silk and then on ten with catgut. The silk cases all healed cleanly and the catgut cases had four hematomas and two infections. Then he changed over en-

SUTURE MATERIAL AND WOUND REPAIR

tirely to the use of silk and a little later in May, 1930, the other thyroid surgeon followed his example. Since then practically all of the thyroids have been done with silk with marked reduction both of hematomas and infections, as is seen in Table I.

This striking improvement in thyroid cases led to the greater use of silk in hernias and open reductions with equally gratifying results when the figures were completed for 1931. (See Table II.)

The incidence of infection in open reduction fell from 26 per cent. to two per cent. and although there were some other changes in technic this seemed to be due almost entirely to the substitution of silk for catgut. We believe that this favorable response is probably due to the minimal tissue reaction which silk produces, to the greater security of hemostasis with silk and to the gentler handling of tissues which the use of silk requires.

During the past seven years our serious wound infections have been reduced from 4 to 1.7 per cent. and the trivial infections from 10 to 5.4

TABLE I
Thyroid Operations

	Totals	Infect.	%	Hemat.	%
1926	57	10	18	16	28
1927	77	13	17	30	39
1928	78	8	10	29	37
1929	163	20	12	60	38
1930	189	4	2	29	15
1930 Catgut	35	2	6	15	43
1930 Silk	154	2	1	14	9
1931	216	4	2	29	13
1930 Av. num. days in Hosp. Catgut - 12					
" " " " " " " Silk - 9					

TABLE II
1931 Silk versus Catgut

	INGUINAL HERNIA						FRACTURE SERVICE					
	Total	Hem.	%	Ser.	Triv.	% Inf.	Total	Hem.	%	Ser.	Triv.	% Inf.
CATGUT	100	14	14	1	4	5	38	11	29	2	5	13
SILK	49	0	0	0	0	0	79	1	1	0	0	0
SILK & GUT	8	2	25	0	3	38	10	4	40	0	1	10
NOT STATED	5	0	0	0	0	0	10	0	0	0	0	0
Totals	162	16	10	1	7	5	137	16	12	2	6	6

per cent. We do not feel that we have reached the irreducible minimum of wound infections and will continue to strive to reduce their incidence still further.

EFFECTS OF SUTURE MATERIAL ON THE TENSILE STRENGTH OF WOUND REPAIR

DR. EDWARD L. HOWES remarked that from the point of view of strength, the function of the suture is to hold the wound edges in apposition until the wound through the process of healing has acquired a strength of its own. Simple incised wounds made in fascia, muscle, peritoneum, and skin sutured with the finest of suture material have a period of four to five days when the strength of the wound is only that attributable to the holding power of sutures. Moreover, this holding power of sutures is more dependent upon the nature of the tissues holding them than upon the thread strength of the sutures. Thus fascia has a greater holding power than muscle. When cat-

gut is used to repair a wound, its thread strength tends to diminish during this first period while the strength of silk remains unchanged. There is also some loss of the holding power of the tissues during this period.

Following this first phase of healing, the wound rapidly increases in strength as a result of the proliferation of fibroblasts and epithelial cells. The time when this second period begins and the rate at which it proceeds depend entirely upon the length of the first period. The length of the first period, in turn, depends upon the extent and character of the exudative reaction. Infection and necrosis prolong the first period and consequently the strength of the second period is manifested later and develops at a slower rate.

Sutures in the wound are foreign bodies and therefore should influence both periods of healing. Besides, the method by which they have been inserted, the tightness with which they were tied, and perhaps their very nature can prolong the first period of healing and subsequently affect the second period.

To demonstrate whether suture materials by their very nature can affect the tensile strength of the healing wound, rectus-splitting incisions were made on either side of the abdomen by Doctor Whipple and Doctor Vivier in a series of dogs. To control trauma and variations in the amount of suture material employed, sutures of exactly the same size and strength were used in both wounds and were employed in exactly the same manner. On one side, interrupted No. 000 plain catgut sutures were used for the peritoneum, interrupted No. 000 chromic catgut for the fascia; and interrupted silk for the skin. On the opposite side, interrupted sutures of A-silk were employed in the same manner. The thread strength of No. 000 catgut is five to six pounds. The thread strength of A-silk varies from three and three-quarters to four and three-quarter pounds. The wounds were tested for strength at daily intervals after suturing, leaving the skin sutures in place.

The results showed that in every instance the wounds sutured with silk were stronger than those sutured with catgut. Besides, in two of the wounds sutured with catgut separation of the peritoneum had occurred, yet these and all of the other wounds appeared to have healed per primam externally. The two wounds with the separations of tissue were not tested for strength.

The number of observations in these experiments on the wounds in dogs were too few in number to tell whether there was a difference in the length of the first period of healing, or whether there was a difference in the rate of accumulation of strength during the first part of the second period. Other experiments on rats have illustrated these points. These wounds in the stomachs of rats were sutured with different sizes of silk and catgut. The strengths of these wounds were tested at daily intervals by distending the stomachs with air and the results are therefore expressed in millimetres of mercury. The details of this method have been described before. Five wounds were tested each day and the data were sufficiently explicit to give smooth curves of healing strength. The results showed that with silk the first period of healing was shortened. With catgut, the first period was

SPINAL ANÆSTHESIA

prolonged. Correspondingly, the wounds sutured with catgut had less strength in the beginning of the second period than the wounds sutured with silk. This more rapid appearance of healing strength with silk and the greater strength of the wounds during the beginning of the second phase of healing occurred regardless of the size of the catgut or silk suture used. The difference, therefore, is attributable to the nature of the suture material rather than its size. It must be pointed out, however, that even though different sizes of both silk and catgut were used without demonstrable differences in strength, none of the sizes employed were of such exaggerated dimensions that healing was interfered with. Examples of the fact that extremely large sizes of catgut retard healing more than the finer sizes of catgut have already been demonstrated by Doctor Harvey and myself.

Microscopical sections have been made of all of these wounds and will be described in the final publication of this work.

ONE THOUSAND SPINAL ANÆSTHESIAS

DR. LAWRENCE W. SLOAN submitted a report as part of a study of the use of spinal anæsthesia at the Presbyterian Hospital of New York made by Dr. Louis M. Rousselot and the speaker, saying that the report was really a study of a group of operative cases in which spinal anæsthesia was employed; that is to say, the group was studied from the point of view of the patient as an operative risk in relation to the anæsthetic rather than to obtain isolated statistics with reference to the anæsthetic. A more complete presentation of the study was contemplated.

The group of 1,000 includes the cases that were operated on under spinal anæsthesia between January, 1928, and May, 1932. This major group has been subdivided into two groups: (1) Those between January, 1928, and January, 1931 (596 cases), and (2) those from January, 1931, and May, 1932 (404 cases). A third more recent group of 100 cases was also briefly reported compared with the other groups. The cases in this last group were anæsthetized under a technic differing from the preceding cases chiefly by the larger doses of anæsthetic drug and ephedrine used, the abandoning of the Trendelenburg position and the use of larger pre-operative doses of sedatives. (The earlier technic was essentially the Labat method.)

The following charts were shown to present briefly some of the findings:

In Chart I the results based on both the entire 1,000 cases and the results in the group of 596 cases are presented. The more detailed analysis was made on the latter group because in this group more complete records were kept. This group of 596 cases also really represents a selected group because in it were included many very poor risks, the choice of the anæsthetic being made on that account. This undoubtedly explains the high *gross* mortality rate (13.6 per cent.) for the group of 596 cases (whereas for the entire group the rate is 11.8 per cent. and for the more recent group of 100 cases 8 per cent.).

About one-fourth of the cases (27.5 per cent.) required a supplementary

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anæsthetic. The incidence of failures was 5.2 per cent. The average blood-pressure drop for intra-abdominal and extra-abdominal operations was almost the same (49/29 and 45/23 respectively).

Whereas the incidence of minor respiratory complications before operation was relatively high in the unsupplemented spinal anæsthesias, the incidence of post-operative pneumonia was relatively low. In the supplemented cases, however, the converse held true. In those cases complicated by a major respiratory complication before operation, post-operative pneumonia almost invariably followed. The incidence of other post-operative complications is also shown in the chart. The highest rate of incidence for both

Chart 1	Number	Percent	Blood Pressure Drop (Average)	Minor Pre-op. Respiratory Complications	Major Pre-op. Respiratory Complications	Post-op. Pneumonia	Severe Post-op. Nausea Vomiting Distention	Severe Post-op. Headache	Post-op. Cardio-vascular Complications	Post-op. Difficulty Voiding	Deaths (Based on 1000 Cases)
Total Cases	1000	100									118 11.8%
Unsupplemented Intra-abdominal Ops.	463	46.3	49/29	26.9%	15.6%	10.5%	16.4%	1.9%	16.0%	2.2%	58 12.5%
Unsupplemented Extra-abdominal Ops.	262	26.2	45/23	22.8%	13.6%	6.5%	2.6%	2.6%	7.8%	1.3%	16 6.1%
Total Unsupplemented Ops.	725	72.5	48/28								
Supplemented Intra-abdominal Ops.	227	22.7		10.8%	9.4%	12.2%	22.3%	.72%	21.6%	4.3%	39 17.2%
Supplemented Extra-abdominal Ops.	48	4.8		14.3%	14.3%	14.3%	7.2%	0	10.7%	3.6%	5 10.4%
Total Supplemented Ops.	275	27.5									
Total Intra-abdominal Ops.	690	69.0									
Total Extra-abdominal Ops.	310	31.0									
Spinal Failures	52	5.2									
Duration of anaesthesia (120 mgs. neocaine): 52 mins. 76% lasted for duration of operation when op. lasted 1 hr. to 1 hr. 15 mins. 32.6% lasted for duration of operation when op. lasted 1 hr. 15' to 1 hr. 30'											
Mortality rates: 40 yrs.-50 yrs. 8.45% 50 yrs.-60 yrs. 25.4%											
"Spinal" deaths: Apparently direct result of anaesthesia: 1 (0.2%) (596 cases) In which anaesthesia was thought contributory: 18 (3.0%) Aver. Bp. drop 82/50 Total: 19 (3.2%)											

complications and mortality was found to be in the supplemented intra-abdominal group.

The average duration of the anæsthetic (120 milligrams of neocaine) was fifty-two minutes. Only about one-fourth of the operations performed lasting one hour and fifteen minutes required a supplementary anæsthetic, whereas over two-thirds of the operations lasting one hour and thirty minutes required a supplementary anæsthetic.

There was only one death in the group (0.2 per cent.) which seemed to be due directly to the anæsthetic but there was a group of eighteen cases in which it seemed fairly reasonable to assume that the anæsthetic contributed (3.0 per cent.). The average blood-pressure drop in this group was 82/50. The mortality rate for the patients between forty and fifty years of age was 8.45 per cent. whereas in the next decade the rate jumped to 25.4 per cent.

SPINAL ANÆSTHESIA

Chart 2 simply shows the distribution of cases from the standpoint of operative procedures performed under spinal anæsthesia. Over one-fourth

Chart 2.		DISTRIBUTION OF CASES	
Intra-abdominal Operations		690	Extra-abdominal Operations 310
Biliary Tract	186		Hernia 111
Biliary Tract ^{Combined with G.I.}	97		Amputation 38
(Cholecystectomies 113)	283		Hemorrhoid 37
Stomach	32		Fistula 19
Intestine	132		Prostate 14
Appendix	153		Kidney 8
(Appendicectomy 127)			Miscellaneous 83
Gynecological ^{Combined with G.I. Ops.}	15		
Celiotomies ^(Explorations and Biopsies)	37		
Genito-Urinary	3		
Miscellaneous	35		
(Splenectomies 12)			
115 Different Procedures		49 Different Procedures	

Chart 3		COMPLICATIONS AND INCIDENTS	
		DURING ANÆSTHESIA	
		(596 Cases)	
Intra-abdominal Operations	Severe	Extra-abdominal Operations	Severe
Nausea	176 (42%) 30	38 (37%) 2	
Vomiting	114 (27%) 13	28 (27%) 1	
Restlessness	37 (8%) 11	12 (10%) 1	
Weak Irregular or Rapid Pulse	35 (8%)	10 (9%)	
Syncope	30 (7.2%) 7	6 (5.9%)	
Others:			
Difficulty Breathing	8	Pain in Shoulder	1
Shallow Respirations	6	"Cramps in Stomach"	1
Rapid Respirations	3	Pressure in Abdomen	1
Pressure in Chest	2	Headache	2
Pain in Chest	3	Sensations in legs	1
Constriction around Chest	1	Diaphoresis	2
Difficulty Swallowing	1	Frankly Uncooperative	1

of the entire group consisted of biliary tract or biliary tract and gastro-intestinal tract operations combined.

Chart 3 shows the complications and incidents which occurred during

the *course* of operation. The total incidence of nausea and vomiting, restlessness, pulse irregularities and syncope did not vary much between the intra-abdominal and the extra-abdominal groups except that in the former the severity of symptoms in general was more marked.

In the more recent group of 100 cases in which larger doses of anæsthetic drug, ephedrine, and sedative were used, it was found that there was a gain of only about fifteen minutes of anæsthesia by increasing the dose of novocaine from 120 to 300 milligrams. The average drop in blood-pressure was almost nil (11/6 as contrasted with the average for the foregoing group of 48/28). There was *almost* always a *rise* in the blood-pressure under the newer technic. The number of failures was about the same (4 per cent.). The gross incidence of deaths was lower (8 per cent.) as was the incidence of pneumonia (3 per cent.—all terminal). The incidence of other post-operative complications was also lower.

The post-operative complications and sequelæ thought to be due to the spinal anæsthesia were also reported:

(1) One case of diplopia due to paralysis of the left lateral rectus muscle which persisted for two months.

(2) One case of injury to nerve roots Lumbar III, VI, V; Sacral I, II, III (partial) resulting in radiculitis and causing weakness of one leg with subsequent almost intractable trophic ulceration of the ball of the great toe.

There were no broken needles and no local or meningeal infections.

BRIEF COMMUNICATION

MECKEL'S DIVERTICULUM PERFORATION BY A FISHBONE

THE perforation of the diverticulum of Meckel by a fishbone produces a serious surgical condition which is fortunately extremely rare. I have been able to find but five cases reported. Blanc¹ reported the case of a forty-one-year-old man operated upon in 1898. Symptoms were of ten days' duration and the patient was observed for an additional five days and then operated upon. A hard fibrous mass was found which proved to be a Meckel's diverticulum with a fishbone in its wall. Recovery was uneventful. Piquand and Grenet,² in 1900, reported an autopsy on a woman of forty-five years with symptoms of over one year's duration. A Meckel's diverticulum perforated by a fishbone was found. Hagler and Stewart,³ in 1920, report the case of a man of thirty-nine years with symptoms of two days' duration with death from peritonitis six days after operation. A Meckel's diverticulum perforated by a fishbone was surrounded by an omental mass. Walkling,⁴ in 1931, reported the case of a boy of eight years who upon operation was found to have an abscess in the abdominal cavity with a Meckel's diverticulum in its centre perforated by a fishbone. Recovery resulted. Wilcox,⁵ in 1932, operated upon a seventy-one-year-old man who had symptoms of forty-eight hours' duration resembling appendicitis. After eleven hours' observation operation revealed a broad-based Meckel's diverticulum with a fishbone protruding for one-fourth of an inch. The fishbone was withdrawn and the diverticulum inverted by the purse-string method and recovery followed. Wilcox's patient had had two previous laparotomies by other surgeons.

The case reported here is that of a girl fifteen years of age first seen at eight o'clock in the evening of Tuesday, June 24, 1930, with pain in the right lower quadrant of the abdomen which was cramplike and very severe. She had eaten fish on Sunday and Monday. At two o'clock P.M., six hours previously, while riding in an auto she began to have pains in the lower abdomen on the right side and the severity gradually increased until at the end of six hours the pains were very severe and the writer was called to see her.

Her past history was unimportant. There was no previous history of gastrointestinal disturbance. She had had pyelitis four years previously.

The general physical examination was that of a well-developed girl who was entirely normal except for the abdomen. There was marked tenderness in the right lower quadrant extending well down toward the pelvis. There was marked rigidity throughout this tender area but no distension. The temperature was 100°, pulse 72 and respirations 20. The white blood count was 13,700 and the differential showed 69 per cent. polymorphonuclears, 29 per cent. small lymphocytes and 2 per cent. large mononuclears. The urine was normal.

Operation was performed at Northwestern Hospital about nine hours after the onset of symptoms. On opening the peritoneum the small intestine which presented was found to be inflamed, and on searching for the appendix turbid fluid was found in the right lower quadrant and also in the pelvis. The fluid was not walled off. The appendix was readily found and delivered and was moderately long and showed evidence of a

BRIEF COMMUNICATION

previous inflammation but was not acutely inflamed at the time. The appendix was removed. A search was made for the cause of the peritonitis and the patient was placed in Trendelenburg position after aspirating the fluid and the pelvic organs were examined visually. At the same time, about the level of the brim of the pelvis there was an object which appeared to be about one-half inch of No. 1 catgut lying on the surface of one of the loops of intestines. On closer examination it was found that this was lying on a Meckel's diverticulum which was only slightly inflamed near its tip. The Meckel's diverticulum was about the size of the thumb of an ordinary rubber glove and the object on the diverticulum was a fishbone which had penetrated the diverticulum about one-half inch from its tip with the sharp end sticking out and the larger end of the fishbone still within the lumen of the diverticulum, thus permitting a constant escape of the intestinal contents. (Fig. 1.) The diverticulum was ligated and removed and the stump inverted with a double row of Lembert catgut suture. A penrose drain was placed in the pouch of Douglas and brought out at the lower angle of the wound.

Convalescence was quite uneventful. The maximum temperature was 101° , pulse 108 and respirations 24. The drain was completely removed June 29, five days after operation.

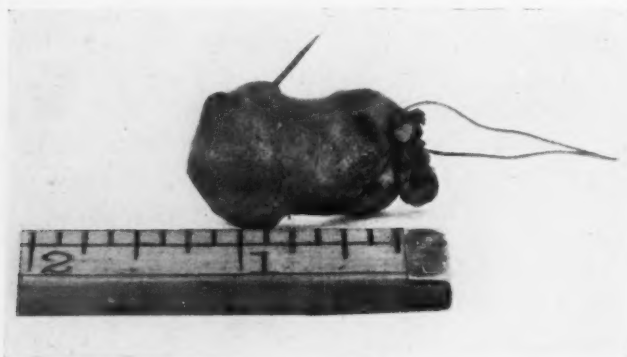


FIG. 1.—Meckel's diverticulum perforated by a fishbone.

The perforation of Meckel's diverticulum by a fishbone is of such extreme rarity that this report of six cases might be considered as of greater interest to a mathematician than a surgeon. On the other hand, it is hoped that this report may help the surgeon to keep this interesting anomaly in mind when examining the abdomen. In the case here reported, failure to search for the Meckel's diverticulum combined with any condition which would have obscured the perforating fishbone might well have resulted in failure to diagnose the cause of the peritonitis.

ROSCOE C. WEBB, M.D.
Minneapolis, Minn.

EDITORIAL ADDRESS

The office of the Editor of the *Annals of Surgery* is located at 386 Park Street, Upper Montclair, New Jersey. All contributions for publication, Books for Review, and Exchanges should be sent to this address.

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